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317.

MEMOIRS OF THE GEOLOGICAL SURVEY.

ENGLAND AND WALES.

THE GEOLOGY OF THE COUNTRY NEAR CHICHESTER.

(Explanation of Sheet 317.)

BY

CLEMENT REID, F.R.S., F.L.S., F.G.S.

With Contributions by
G. W. LAMPLUGH, F.G.S., and A. J. JUKES-BROWNE, F.G.S.

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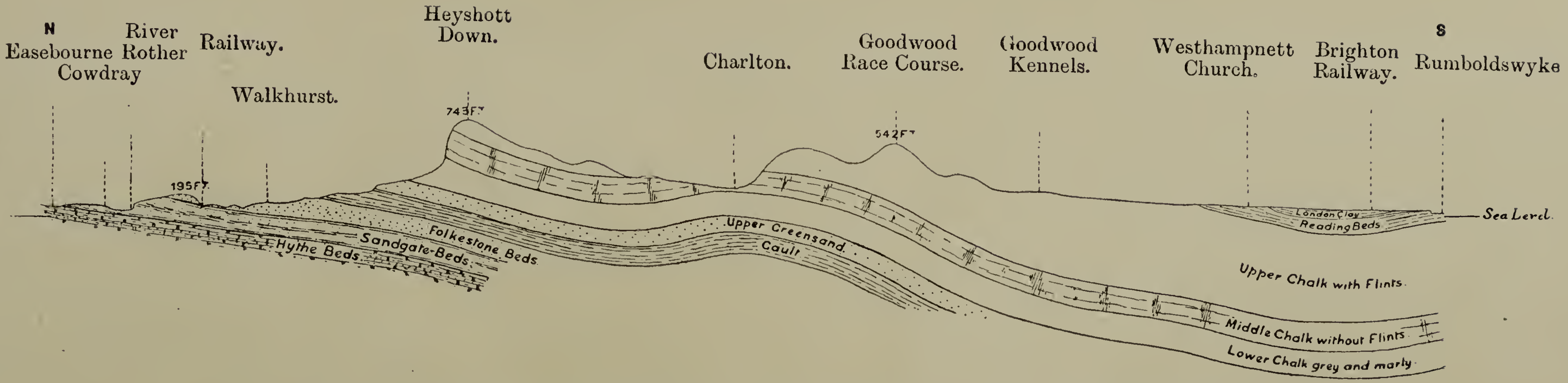

FIG. 1.—*Section from Easebourne across Heyshott Down to Rumboldswyke.*

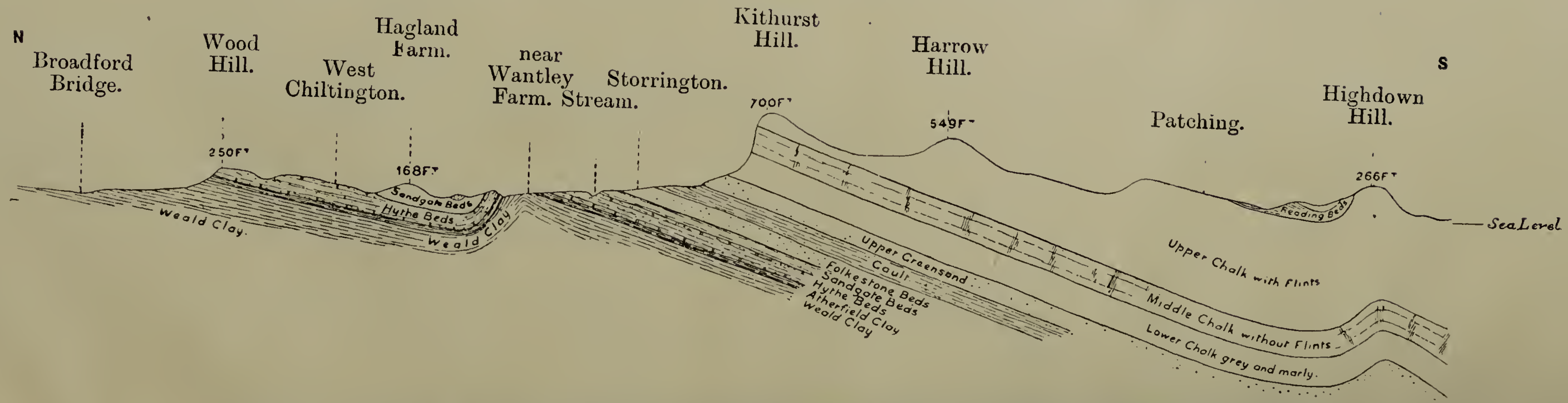

FIG. 2.—*Section from Broadford Bridge across Kithurst Hill to Highdown Hill.*

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Geology

PREFACE.

The country described in this Memoir includes a large tract of the South Downs, which present a bold front of Chalk scarps on the north, overlooking the great Wealden area, a portion of which is represented on the map. Southwards the Chalk descends gradually to a low level, where it forms a syncline, in the hollow of which Lower Eocene strata are preserved. In this comparatively level tract the strata are extensively covered by Pleistocene deposits of brick-earth and gravel. Geologically the area has been described and illustrated in the works of Fitton, Frederic Dixon, P. J. Martin, and Dr. Charles Barrois, and it has been partially described in the Geological Survey Memoirs by Mr. William Topley and Mr. A. J. Jukes-Browne.

The original Geological Survey of this area on the one-inch scale was made by H. W. Bristow and Frederick Drew, and published in 1864. The re-Survey on the six-inch scale was carried on between the years 1884 and 1890 by Mr. Clement Reid, who mapped the southern area, including the Chalk Downs. The remaining portion was for the most part surveyed by Mr. G. W. Lamplugh in 1899 and 1900, a few square miles near Midhurst having been previously mapped by Mr. C. E. Hawkins.

In the course of the Survey, assistance has been rendered by Mr. William Hill, Mr. J. Vincent Elsden, and Mr. R. M. Brydone, while useful records of the strata have been furnished by well-sinkers.

J. J. H. TEALL,
Director.

Geological Survey Office,
28 *Jermyn Street, London.*
25th March, 1903.

24

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CONTENTS.

PAGE

Preface by the Director - - - - - - - - - - iii

Chapter I.—Introduction - - - - - - - - - 1

Chapter II.—Wealden - - - - - - - - - - 4

Chapter III.—Lower Greensand - - - - - - - 7

Chapter IV.—Selbornian (Gault and Upper Greensand) - - 13

Chapter V.—Chalk - - - - - - - - - - 19

Chapter VI.—Eocene - - - - - - - - - - 33

Chapter VII.—Drift - - - - - - - - - - 37

Chapter VIII.—Economic Geology - - - - - - - 46

Appendix.—List of Principal Works on the Geology of the District - - - - - - - - - - - 48

Index - - - - - - - - - - - - - 49

LIST OF ILLUSTRATIONS.

Fig. 1. Section from Easebourne across Heyshott Downs to Rumboldswyke - - - - - - - - *Frontispiece*

, 2. Section from Broadford Bridge across Kithurst Hill to Highdown Hill - - - - - - - - *Frontispiece*

„ 3. Ammonites [Hoplites] interruptus, *Brug.* - - - - 14

„ 4. Ammonites [Schloenbachia] rostratus, *Sow.* - - - - 14

„ 5. Inoceramus concentricus, *Park.* - - - - - - 14

„ 6. Ammonites [Acanthoceras] rotomagensis, *Brongn.* - - - 20

„ 7. Ammonites [Schloenbachia] varians, *Sow.* - - - - 20

„ 8. Scaphites æqualis, *Sow.* - - - - - - - - 20

„ 9. Inoceramus mytiloides, *Mant.* - - - - - - 24

„ 10. Rhynchonella Cuvieri, *d'Orb.* - - - - - - - 24

„ 11. Micraster coranguinum, *Leske* - - - - - - - 28

„ 12. Marsupites testudinarius, *Schloth.* - - - - - - 28

„ 13. Holaster planus, *Mant.* - - - - - - - - 28

„ 14. Echinocorys scutatus, *Leske* - - - - - - - 28

GEOLOGY

OF THE COUNTRY NEAR

CHICHESTER.

CHAPTER I.

INTRODUCTION.

Sheet 317 of the Geological Survey Map takes in an area of 216 square miles, all included in the county of Sussex. The central part of the district is occupied by the South Downs, which stretch from east to west as a wide belt of undulating southward-sloping uplands, bounded on the north by the high chalk-escarpment which overlooks the Weald. This escarpment rises to 818 feet at Linch Down. On the south the Downs usually end in a lower bluff, which marks the position of an ancient partly-obliterated sea-cliff; and below this is a flat coastal-plain, which extends continuously to the sea. These are the main features; the details will be described further on.

One river of importance, the Arun, traverses the country from north to south, and with its tributaries drains about two-thirds of the area. Over the remaining area most of the water escapes by underground courses to the Lavant, or drains into small streams which reach the sea near Bognor and Pagham.

Within the area lies the ancient town of Chichester, as well as Arundel, Midhurst, Petworth, Pulborough, and numerous villages. The position of the settlements has been decided mainly by the possibility of obtaining water, no place of importance lying on the Weald Clay or Gault, nor on the high Downs, where water can only be found in deep wells.

The district is mainly devoted to agriculture and sheep-pasture; but contains also much woodland, beech on the Downs and oak in the Weald. There are neither mines nor manufactures, and the mineral products raised, consisting of chalk, brickearth, tile-clay, gravel and sand, are almost entirely used within the district, for building purposes, agriculture, or road-making.

The formations represented on Sheet 317 are the following:—

Recent	Alluvium.	
Pleistocene	Brickearth.	
	Valley Gravel and Coombe Rock.	
	Hill Gravel and Flint-rubble.	
	Marine Gravel (south of the Downs).	
	Clay with Flints and Tertiary *débris* (overlying Chalk).	
Eocene	London Clay.	
	Pebble Beds.	
	Reading Beds.	
Upper Cretaceous	Upper Chalk.	
	Middle Chalk.	
	Lower Chalk.	
	Upper Greensand.	Selbornian.
	Gault.	
Lower Cretaceous	Folkestone Beds.	Lower Greensand.
	Sandgate Beds.	
	Hythe Beds.	
	Atherfield Clay.	
	Weald Clay.	

Nothing is yet known about the strata which underlie the Weald Clay; but as far as can be judged from neighbouring areas, a great thickness of Lower Cretaceous and Jurassic Rocks would be met with. It is not probable that any minerals worth mining occur within several thousand feet of the surface.

A general southward dip is caused by the broad anticlinal arch of the Weald, on the southern side of which the whole of our district lies. By the destruction and planing down of the higher parts of this arch, rocks have been laid bare in the north which to the south are buried under a great thickness of newer strata; these newer strata form the northern edge of the broad syncline known as the Hampshire Basin. Not only does this great disturbance affect our area, but we have also various minor parallel folds, which form ripples on this big wave. It will be seen, on examining the Map, that several of these folds occur within the area. An anticline enters the district north of Storrington, bringing up Wealden strata; then it runs westward to Watersfield, where it dies out. Another anticline commences near Bury (south of Westerfield), and then brings up an inlier of Lower Chalk near Upper Waltham, and a long tongue of Middle Chalk, which extends as far as West Dean. West of that point the anticline causes two more inliers to appear, and then passes out of our district. Another sharper anticlinal fold brings up Chalk at Highdown, and can be traced westward to Barnham, with Eocene strata on either side. Still another commences near the termination of this one, but not in the same line, and brings up Chalk south of Chichester.

These sharp folds, in the southern part of our area, make, however, scarcely any sign at the surface, for they have nearly all been planed down to a uniform level and subsequently covered with Drift deposits. The streams which now cross the coastal plain follow courses decided by slight irregularities in the surface of the Drift; they quite ignore the anticlinal and synclinal structure below. Should the land again rise, the deeper trenching of the stream courses would cut across the folded strata below, and we should then see a series of valleys which, like those of the Weald, would seem to be independent of the hardness or softness of the strata through which they have been cut.

CHAPTER II.

WEALDEN.*

The Weald Clay, which is the only division of the Wealden strata occurring at the surface in the district, is brought up, as already described, to the north of Petworth, Pulborough, and West Chiltington. A tongue of it also appears along the axis of the minor anticline north of Storrington; but only the upper part of the formation is here exposed.

The area under consideration in this Memoir includes a considerable proportion of the tract mapped and described in detail, with remarkable accuracy, by P. J. Martin so long ago as 1828.† Martin noted the occurrence of definite courses of sand and of Sussex Marble in the Weald Clay of this district, by which the deposit could be divided into distinct belts, and although these courses may not be quite so regular and continuous as he believed, his statement of the general succession has been satisfactorily verified. The occurrence of the sandy horizons has some economic importance, as they are the main source of water-supply in the Weald Clay tract; and, moreover, by their admixture with the clay where near the surface, they change the character of the soil from a stiff intractable clay-land which, under present conditions, will not pay for cultivation, to a more readily arable loam which is still, for the most part, under tillage. Hence beds of this material underlie the major portion of the arable land in this part of the Weald, while the unmodified clay-belts are nearly all under grass or woodland. The beds of sand are, however, usually too thin or too much interstratified with clay to render the soil actually "light," especially as the clays tend everywhere to "creep" and become mixed with the sands along their outcrop. The water supply from wells in the sands is often tainted with mineral matter in solution, and is usually only sufficient in quantity for household supply, but is nevertheless important in a district where no other safe source is available.

The uppermost division of the Weald Clay, so far as the very scanty exposures enable one to judge, is a dark blue shaly clay, probably of the character of the Wealden Shales of the Isle of Wight. It weathers at the surface to a stiffly plastic brownish-yellow clay, and occupies the lower slopes beneath the bold escarpment of the Hythe Beds of the Lower Greensand and a broad belt of low ground to the northward. Beds of this description probably extend uninterruptedly at the same horizon all round the Weaden depression.

Below this division come more silty clays associated with thin beds of fine yellow loamy sand or sand-rock, with a little concretionary iron rag-stone in places. Owing to the insufficiency of the exposures it is not possible to assert with confidence that the sand-beds are absolutely continuous; they may, perhaps, occur in detached lenticles of irregular horizontal extent; but sand was found here and there at approximately the same horizon from the eastern to the western limits of the tract surveyed, and was apparently thickening westward. Usually only 4 or 5 feet of sand was visible in any particular section, but the full thickness would probably in most cases have been found to be greater if the exposure had been complete. The greatest depth was noticed a little to the north of the limits of the map in a road-cutting at Gunter's Bridge, one mile north of Petworth, where 10 feet or more of sand and sand-rock with thin clay-partings is exhibited, one seam being exceptionally coarse in grain for these beds. In an exposure in a gully in the woods south-west of Hawkhurst Lodge, three miles farther east (also in Sheet 301), the sand-rock contains a seam of pebbly conglomerate, apparently of local and contemporaneous derivation, made up of fragments of soft sandstone and pellets of clay, with fragments of bone and wood, resembling the conglomerate bands often associated with the sandstones of the Variegated Series of the Wealden in the Isle of Wight. On the eastern slope of the Arun Valley at Toat Wood and Toat Farm, just within the present sheet, a sand-rock of this belt has been dug in old quarries, probably as a sandstone. The clay which immediately overlies the sands of this as well as of the lower horizon is frequently of a bright red colour.

---

* By G. W. Lamplugh.

† "A Geological Memoir on a Part of Western Sussex,"

The sands generally form a gentle feature along their outcrop, but owing to their slight thickness and the above-mentioned "creeping" of the clays on the slopes and consequent mixing of the beds, it is rare that sand is visible in the feature, the exposures being found usually in gutters and ponds on the lower part of the dip-slope, under a thickness of 2 or 3 feet or more of clay. The dip, which is to southward, appears, from calculation, rarely to exceed 1° or 1½°, and the dip-slopes are therefore of great breadth in proportion to the thickness of the bed. Under these circumstances it was not found practicable to map the beds of sand separately from the accompanying clay and silt, and the plan was therefore adopted of mapping out approximately the limits of the zones wherein the clay is associated with sandy intercalations so that they may be distinguished from the zones in which such intercalations are absent. The same remarks apply also to the method adopted for indicating the horizon of the Sussex Marble next to be described. Difficulties were found in carrying out this plan towards the northern edge of the area in the vicinity of the Arun, and it remains to be proved by further survey whether the divisions can be followed beyond the ground already mapped. It would certainly be advantageous, in studying the detailed structure of the country, if the thick mass of the Weald Clay could thus be broken up into zones.

Below the silty clays with sands, we find in the eastern part of the district examined a belt of stiff, dark, shaly clay, probably somewhat pyritous, containing a bed of Paludina-limestone or Sussex Marble ("First course of Sussex Marble" of Martin) ranging from a few inches to 2 feet in thickness. This limestone was formerly much dug for road mending and building, and many of the farmsteads near its outcrop are partly built on it; it is still being raised on a small scale in fields one-third of a mile north of Broadfordbridge and near Oldhouse Farm. In going westward, however, all trace of this stone-band was lost before crossing the London, Brighton, and South Coast Railway at Adversane, and it was not again seen in the area examined, though, according to Dr. Martin, it is found west of the Arun to the northward of the ground at present mapped.

This division is the lowest seen in Sheet 317, where it occupies a little triangular tract only about a mile long from east to west and half a mile broad from south to north in the extreme north-eastern corner of the map.

It is succeeded farther north, in Sheet 301, by another sandy series consisting of laminated pale blue, dark blue, and grey clay and silt with layers of sand and a thin band of calcareous sandy flagstone ("The Second Sand" of Martin). A good section was obtained in this division in a new well at a cottage opposite to Marringdean Farm (Sheet 301), 1¼ miles south of Billingshurst Station, where it was penetrated to a depth of 40 feet. A seam of silty clay a few feet above the bottom of the well contained well-preserved plant-remains, and a collection of these was made from the spoil-heap and submitted to Mr. A. C. Seward, F.R.S., who kindly undertook their examination, and determined the following forms:—

Weichselia Mantelli, *Brongn.*
Onychiopsis Mantelli, *Brongn.*
Brachyphyllum sp. (?)

The flora of the Weald Clay, as distinguished from the Hastings Beds, is imperfectly known, so that the occurrence of these plants is of some interest, though they all belong to well-known and widely distributed Wealden forms. The horizon at which they occur is probably about midway in the Weald Clay of this part of Sussex.

The calcareous flagstone mentioned above is apparently at the most only a foot or two thick; it was formerly dug in several places between Marringdean Farm and Lording's Farm, but the present exposures are poor and scanty. The division as a whole was traced westward to the Arun at Lee Farm; west of the Arun it passed beyond the northward limits of the ground examined.

CHAPTER III.

LOWER GREENSAND.*

According to the classification of the original Survey Map, the uppermost portion of the clayey deposits which occur immediately beneath the Lower Greensand escarpment is supposed to represent the Atherfield Clay, though definite evidence on this point is rarely forthcoming. A few marine fossils were, however, found long ago in nodules from this clay at the brickyard at Harwood's Green, near Pulborough, which serve to differentiate it at this locality from the underlying Weald Clay of fresh-water origin; and during the new survey some further specimens were obtained from this place.

There are occasional indications that the clay becomes interstratified with silt and fine sand towards its junction with the overlying Hythe Beds, and that in passing southward the base of the latter strata contains an increasing proportion of clay.

The broad grounds for the subdivision of the Lower Greensand into the supposed equivalents of the Hythe Beds, Sandgate Beds, and Folkestone Beds of East Kent, are readily grasped in this part of West Sussex, though the exact boundaries of the sub-divisions are usually more or less vague, seeing that they rest entirely upon lithological differences which are subject to much local variation. The Hythe Beds are characterised, as in Kent, by irregular calcareous stone-bands among half-indurated loamy glauconitic sand, with the local development of impersistent layers or concretions of chert. The calcareous sandstone has been much used for building, and the chert is extensively dug for road-mending.

The Sandgate Beds are variable in composition, but contain more clay and silt than the underlying and overlying divisions. In the western part of the district a thick bed of sand near the base of this series is partly composed of smooth polished grains of brown iron-ore. It has been suggested that this ferruginous sand might be of some economic value, but the average percentage of iron (23%) is probably too low to bear the cost of carriage. The iron-sand disappears rather suddenly at a short distance to the eastward of Selham. The Sandgate Beds are for the most part destitute of fossils, but a richly fossiliferous band was found, consisting of ironstone crowded with the casts of marine shells, at the top of the iron-sand, in two hitherto unrecorded localities near Midhurst (June Lane, and the river bank due south of Cowdray Ruins). In the stream-bed east of Ambersham Common, some plant remains, including traces of *Weichselia*, were collected from a thin band of sandstone.

The Folkstone Beds consist of sharp sand, strongly current-bedded, with ironstone concretions and thin partings of pipeclay. Excepting the cast of a fragment of wood with teredo-like borings, no organic remains were found in these sands. At the top of this division, immediately below the Gault, the sand is indurated into a hard grit-band, from 2 to 4 inches thick, of a deep red colour, which is persistent throughout the area examined.

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* From Mr Lamplugh's notes.

A comparatively rapid thinning away southward of the Lower Greensand as a whole causes increasing difficulty in mapping the sub-divisions in working eastward, owing to the persistent southerly trend of the escarpments. This difficulty is especially felt on the southern side of the anticline near Storrington.

Atherfield Clay.

As already mentioned, there is much difficulty in obtaining definite evidence respecting the Atherfield Clay, which, on slender grounds, has been supposed to form a continuous base to the Lower Greensand series around the Weald. The best exposures of this clay observed in the district lie outside the margin of the present map, about a mile to the eastward of its boundaries, in Sheet 318, in road cuttings at Warminghurst and again two-thirds of a mile south of Warminghurst, on both sides of the Greenhurst anticline. In the latter section the sandy Hythe Beds are seen to pass down into clay, at first greyish-brown, but deep chocolate-brown below, containing small phosphatic concretions, with casts of marine shells. The thickness of the clay here apparently does not exceed 20 feet and may be less. Immediately below it there is dark blue shaly clay, evidently the topmost bed of the Weald Clay, and the junction appears, as usual, to be quite sharp. A few phosphatic nodules from the marine clay were seen in the spoil-heap from a small excavation at the spring 200 yards south-east of Thakeham Church, and at two or three other spots on the escarpment farther to the north-westward. Chocolate-brown clay was likewise observed in the same position in other localities, both east and west of the Arun, though without direct evidence for its marine origin. Hence it may be regarded as certain that the Atherfield Clay is present throughout the area examined, though probably of insignificant thickness. This confirmation of the old map in the matter is the more satisfactory since the new railway cutting at Redhill, in Surrey, on the opposite side of the Weald, showed an unexpected absence of the Atherfield Clay. The presence of the chocolate-brown clay in the Sussex sections is noteworthy, as a clay of precisely similar aspect forms part of the Atherfield Clay of the Isle of Wight, and was likewise found at the same horizon in the new colliery shafts at Dover.

Hythe Beds.

This division usually is characterised by the presence of irregular stone-bands in hassocky loam. Sometimes these are large, round, or tabular discontinuous concretions set in sand or soft sandstone—indeed, they would probably always appear as lenticles if we could see large sections. There are also limy grits, and in places, especially between Petworth and Bedham, irregular tabular sheets of chert, arranged one over the other in broken columnar fashion. Fossils are rare throughout. A few limas were noticed in the hassock, and occasional obscure casts of bivalves in soft sandstone; in one of the chert-pits between Brinksole and Bognor was a layer containing many badly preserved shells, but no cephalopods were seen. The presence of clay interstratified with the division is shown by the Midhurst Waterworks boring, and there appears to be a similar lenticular band of fine stiff unctuous clay 300 yards east of Little Common near Tillington.

The Hythe Beds contain no workable chert east of the Arun, and the sandstones which characterise their lower portion in the Pulborough district and farther westward are scarcely recognisable in the eastern part of the area examined, where the beds consist of sandy "hassock" with concretionary limestone in lenticular masses and sheets.

It is unnecessary to describe the numerous exposures of Hythe Beds, which can be examined in various natural sections and in quarries opened for the stone; we will merely mention the leading sections which illustrate the character and thickness of the deposits. The best section of the base is seen in the bank on the east side of the pond belonging to the Upper Mill at Little Bognor near Fittleworth. This shows:—

	Feet.
Hard sandstone with hard sands (cherty and loamy)	5
Soft sandstone, rather harder than below	3
Soft sand and sand-rock nearly black, banded pale and dark yellow and green	3
Lumpy, irregular, nodular sandstone, yellow and dark green, ferruginous in places; with soft loamy lenticles between the beds	9
Flaky hassock, with dark green, almost black, sandy layers, and impure loamy sandstone	5
passing into	
Yellow loam	2
passing into	
Greyish and yellowish loamy clay	1

In similar beds just below the road, casts of shells (*Avicula*, etc.) were noticed in a dark-green hassock, which also contained small soft brown bits like decomposed phosphate or bone, and rounded pebble-like bits of sandstone like neighbouring beds.

Another exposure, which exhibits the whole of the Hythe Beds in one section, will be found in the road-cutting at Jackets Hill, a place exactly at the eastern limit of our area and immediately north of Hills and Hamper's Farm. The section, which is worthy of more detailed study, is as follows:—

	Feet.
Like beds below, but hassock predominates (extends to the cottages at the north foot of the hill, where Sandgate beds probably come on)	50 to 55
Alternations of concretionary sandstone in badly stratified masses, with loamy hassock; sandstone predominant	40
Hassocky sandstone with pyrites	4
Knotty sandstone	1
Rather clayey sand, as below	7
A band of concretions 3 feet in diameter, concretionary sandstone bands and hassock (not well seen)	9
Rather clayey sand, harder than that below, with soft sandstone with dark mottling	4
Soft loamy greensand	3

At south side of hill at foot of bank, obscure: probably clayey loam. Below this water oozes out, and the base of the Hythe Beds is mapped - - - - - about	12
	130

The above section illustrates the eastward thinning of the beds, for only three and a half miles to the west-north-west, at Pulborough, a well sunk in 1900 by Messrs. Duke and Ockenden proved nearly 181 feet of strata belonging to this division. The well is in the corner of the field adjoining the churchyard, north-east of the railway station, on the top of the hill, close to the brickyard and sandpit. The well starts near the top of the Sandgate Beds; the dip is rather steep, apparently 10° or 15°, the thickness therefore will be slightly exaggerated. The descriptions given below are misleading, the loamy Hythe Beds (hassock) being called "clay." The Sandgate Beds probably extend to 83 feet, and all the rest is Hythe Beds; the bottom sandstone being probably that at the base of the Hythe Beds. The well-sinkers section shows:—

		Thickness. Feet.	Depth. Feet.
Sandgate Beds	[*Dug Well*] - - -		30
	Sand-rock - -	8	38
	Sand with clay - - -	40	78
	Hard clay - - - - -	5	83
Hythe Beds	Clay and greensand - -	14	97
	Clay - - - - - -	22	119
	Clay and sand - - - - -	80	199
	Rock and clay - - - - -	19	218
	Clay and sand - - - - -	3	221
	Rock and clay - - - - -	4	225
	Sand and clay - - - - -	3	228
	Rock and clay - - - - -	15	243
	Layers of hard and soft sand-rock	21	264

Even if the dip amounts to 15°, the thickness of these strata will only be reduced by about 4 per cent.

SANDGATE BEDS.

This division forms a wide belt stretching nearly across our district, from Trotton, through Midhurst, Fittleworth, Pulborough, and Storrington. The Sandgate Beds, which are best exposed in the numerous sections around Pulborough, are characterized by the beds of silt and clay which they contain; but they include also some beds of sand which, in isolated sections, can scarcely be distinguished from the Folkestone Sand, particularly in the north-eastern part of the ground. The fossiliferous nodules which have long been known to occur in this division in two or three localities in the Pulborough district were observed in a few other unrecorded places also, as mentioned below. The horizon on which these fossils occur is probably roughly equivalent to that at Midhurst, described in 1899,* though the localities seem to have few species in common.

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* Summary of Progress for 1899, pp. 136, 137.

The Sandgate Beds are so variable, and their upper and lower limits are so indefinite, that the most convenient method of description will be to mention the principal sections in order, passing from west to east.

Near the western limit of our area, and thence eastward to a little beyond Selham, the lower part of this group is a well-characterized coarse sand, full of polished flakes and grains of deep brown iron-ore. As this makes a good feature, with featureless ground below, it was at first taken as the base of the division, though the old map seemed to have taken a somewhat lower line. This bed disappears suddenly east of Selham, being last seen below Barnetts Mill, where it seems quite strongly developed. In connection with it, the above-mentioned fossiliferous ironstone nodules were found in June Lane, Midhurst, and in the river-bank at King John's Walk, Midhurst. The fossils are bivalves and univalves in the state of casts. The following forms have been named by Mr. E. T. Newton and Dr. F. L. Kitchin :—

June Lane, Midhurst :
Cardium ?
Corbula striatula ? *Sow.*
Cytheræa ?
Nuculana scapha, *d'Orb.*
Tellina (Linearia) cf. concentrica, *d'Orb.*
Actæon sp.
Aporrhais sp.
Trochus ?

River Bank due south of Cowdray Ruins :
Cucullæa sp.
Exogyra sinuata ? *Sow.*
Nuculana sp.
Trigonia sp. (group "Scabræ").
Actæon sp.
Cerithium ?
Trochus sp.

Probably the dying out of this bed southward is indicated in the banks of the stream south-east of Ambersham Common, where a curious mixture of clay with coarse greenish grit passing into iron-grit is seen at the north-east corner of the Common. Farther south occurs a band of soft micaceous sandstone associated with clay, and in this sandstone are bits of ferns and other plant remains, perhaps including fragments of *Weichselia Mantelli,* Brongn. Perhaps the southern trend of the scarp brings the marine iron-grit to an end ; for, as already observed, there is a general tendency for the Lower Greensand to thin out in that direction.

Below this iron-grit, everywhere east of the place where it crosses the Rother at Midhurst, there is a band of clay or clayey loam. This clay was included in the Sandgate Beds in the old map, and was probably the reason for carrying their base below the iron-grit farther west. I (G. W. L.) should have preferred to leave this loam and clay with the Hythe Beds, as it is lithologically not much removed from them, and these beds undoubtedly do include lenticles of clay, while the coarse iron-grit betokens a change of conditions. I therefore held to the base of the grit as long as it lasted ; but then found that on going farther east it was necessary to go down to the bottom of the clay to make a division between the Sandgate and the Hythe Beds. Then, working backwards, a line was drawn below this clay up to Midhurst, and this line is that adopted on the map. A brickyard has been opened in the lowest bed of clay at Fittleworth; but there, according to the old map, it had been included in the Hythe Beds.

The upper parts of the Sandgate Beds in the Midhurst area are silts and black silty micaceous clay, with fine white sand and sand-rock. The top of the highest clayey band has generally been taken for the division between Sandgate and Folkestone Beds; but the line is not satisfactory, as all these clay beds are lenticular, and it is quite likely that they invade higher or lower horizons at different places.

In the eastern part of our area the best sections of Sandgate Beds are seen in lanes near Pulborough; at Park Farm, Pulborough Church; and Marehill ("Codmore Hill," of the Weald Memoir and old map, is at Hesworth Common, near Fittleworth, and is not the Codmore Hill north of Pulborough). The base seems to be clayey loam passing down into the hassock of the Hythe Beds. Above this comes fine sharp sand or sand-rock, white or stained red or yellow, making a bold feature east of Pulborough, and quarried for moulding sand. Apparently there are sometimes two beds of this sand, with a silty or clayey parting containing fossiliferous ferruginous nodules. Then follow dark shaly silts or muds. The lower clays and silts have large irregular concretions of ironstone, crowded with casts of marine fossils — *Trigonia*, *Terebratula*, etc. Fossils were noticed in these in a wood north of Park Mound (good); in the railway cutting (very much weathered); on the west side of Gravel-pit Plantation near Washington; at the edge of the wood east of Threal's Farm (one mile south of West Chiltington); and at Hurston Place. The best locality for collecting the fossils is, however, the lane mentioned in the Weald Memoir, at Park Farm, near Pulborough, and in the adjacent wood.

FOLKESTONE BEDS.

The sand and sand-rock immediately below the Gault is generally sharp and clean. Sometimes it is white and of very fine quality, sometimes yellow and rusty, and sometimes, especially in the upper part, crimson in patches, apparently from the decomposition of some iron nodules. It often becomes coarse, with pebbles up to a quarter of an inch diameter or larger in the lower part, and it is wonderfully cross-bedded. No fossils whatever have been seen in it in this area, except a trace of wood in the "carstone" (concretionary ribs of ironstone) by which it is traversed. Just below the Gault it is cemented into a hard band, two to four inches thick, of a crimson colour and coarse gritty texture, which forms an excellent line of division, and is generally traceable. This is dug occasionally for walling. Like the other divisions of the Lower Greensand, the Folkestone Beds become thinner as they are traced towards the south-east.

CHAPTER IV.

SELBORNIAN (GAULT AND UPPER GREENSAND).

The two divisions which are described in this Chapter have been grouped together by Mr. Jukes-Browne as one formation, named the Selbornian; for the old lithological division between Gault and Upper Greensand is not one that can be used in a classification depending on time. The line between the clayey Gault and the sandy Upper Greensand varies its position so greatly, that the Upper Gault of the east of England finds its true equivalent in the sandy strata known as the Blackdown Sands in Devon, and the Gault of Dorset represents only the Lower Gault of Folkestone.

The palæontological zones into which the Selbornian is divided are as follows:—

Upper Greensand and Upper Gault	Zone of Pecten asper.
	,, ,, Ammonites rostratus.
Lower Gault . .	,, ,, ——— lautus.
	,, ,, ——— interruptus.
	,, ,, ——— mammillatus.

It is doubtful, however, whether the lowest zone, that of *Ammonites mammillatus*, is represented in West Sussex.

GAULT.

The Gault stretches across West Sussex, forming a strip of low-lying heavy clay land, often a mile in width. Though so well represented in our area, but little can be said about it, for sections in this slippery clay are rare, and soon become obscured, and few wells penetrate it to any great depth. Its total thickness is probably between 200 and 300 feet. The part just above the grit-band mentioned in the last Chapter as occurring at the top of the Folkestone Sands is often seen; but above this there are few sections. Mr. Lamplugh noticed grit-grains mixed with the clay for a few inches above the base in the excellent section at Fittleworth station, and Mr. Jukes-Browne gives the following account of the basement-bed, with which, it will be observed, he classes the thin grit:—[*]

"How far the greensand with phosphatic nodules which forms the base of the Gault near Petersfield extends to the east is not yet known, but it does not reach to the outcrop south of Midhurst, for there, according to the late Mr. Topley, the junction of Gault and Lower Greensand is a red ferruginous grit without fossils or phosphate nodules.

"Topley observed the same bed of red grit farther east, 'in the road west of Burton Church, south of Petworth station; and also in many of the streams which cross the outcrop of the Gault, the hard grit often making a small fall in the stream-bed.'

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[*] Cretaceous Rocks of Great Britain, vol. i. p. 114, Mem. Geol. Survey.

"Still farther east, at Sullington, between the valleys of the Arun and the Adur, the same red grit is seen again. Topley says, 'an excellent section is seen in the road north-east of Sullington, where the grit is [between] two and three inches thick. Here the land below the grit is clayey for a few inches.'

"This junction, as seen in a cutting on the railway, near Lower Fittleworth, was described in 1869 by Mr. G. Maw,* who gives the section as follows:—

FOSSILS OF THE GAULT.

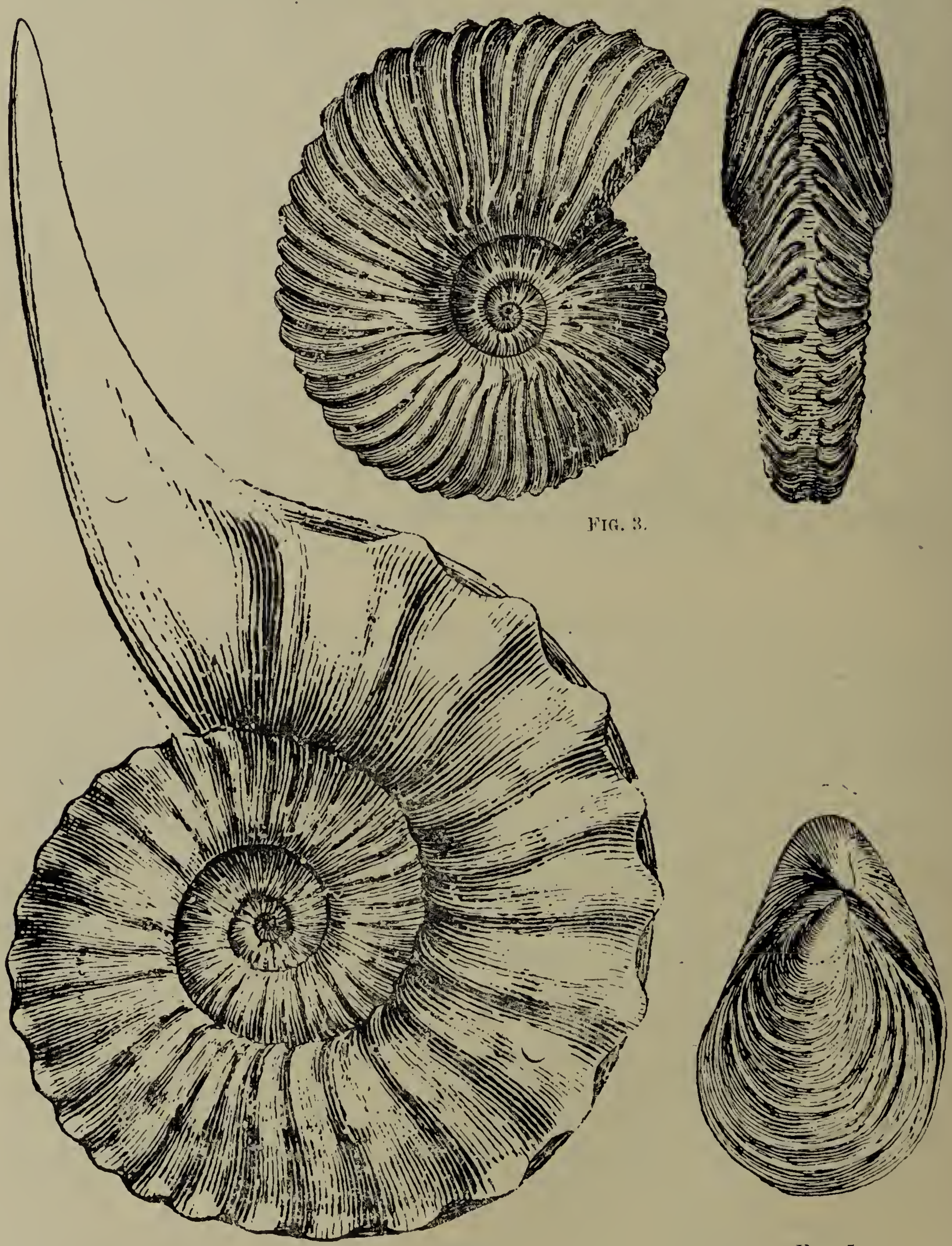

FIG. 3.

FIG. 4.

FIG. 5.

FIG. 3. Ammonites [Hoplites] interruptus, *Brug.*
FIG. 4. Ammonites [Schloenbachia] rostratus, *Sow.* (reduced).
FIG. 5. Inoceramus concentricus, *Park.*

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* Geol. Mag. vol. vi. p. 335.

	Ft.	in.
Ferruginous gravel	5 or 6	0
Gault clay	10	0
Hard blood-red ferruginous conglomerate	0	4
Yellow and orange sands which for a few inches below the conglomerate are stained bright blood-red	30	0

"He describes the conglomerate as maintaining a uniform thickness of about four inches, and as abounding in small quartz pebbles, which are held together by the ferruginous matrix. He also remarks that the line of demarcation is remarkably definite, 'no gradation existing between the red stratum and the Gault above, or the Lower Greensand below.'

"Mr. R. M. Brydone informs me that about 20 feet of Gault clay can now be seen in this cutting, and that fossils are very scarce and badly preserved, being all converted into selenite, which is very abundant; also that the clay is much cracked, the surfaces of the cracks being coated with rust-coloured films.

"It would appear, therefore, that throughout the west of Sussex to the valley of the Adur the base of the Gault is formed by the grit-bed above described, which is not associated with any layer of phosphatic nodules. In this region, therefore, there does not seem to be any representative of the zone of *Ammonites mammillatus.*

"Mr. Brydone also communicates the following information (1898):—'Some years ago a well was sunk near the base of the Gault north of Graffham, the surface of the ground at the spot being about 30 feet above the horizon of the red ferruginous grit, which is visible in the bed of a stream close at hand. The clay brought up yielded *Inoceramus concentricus* (Fig. 5) in abundance, and a few other fossils.' The fossils were sent to me by Mr Brydone, but few were specifically determinable; they include the following:—

"Hamites intermedius or attenuatus.
Hamites punctatus?
Aporrhais carinata.
Bellerophina minuta.
Natica clementina ?
Scalaria sp. (young).
Inoceramus concentricus.
Leda phaseolina ?
And other obscure bivalves."

From brickyards in the Gault at Pitsham near Midhurst, and at Hardham near Pulborough, Mr. Lamplugh obtained fragments of Ammonites (probably all *Amm. interruptus* (Fig. 3) and varieties) but no other fossils.

The middle part of the Gault is thus described in Topley's Memoir on the Geology of the Weald (p. 150):—"In the railway cutting just west of Elstead Station there is a section of Gault which appears to be about in the middle of that formation. The clay here contains some hard calcareous nodules with phosphate of lime. In the road between Burton and Duncton, just opposite the road which goes off to Bound House, there are some nodular masses of clay-ironstone with the concentric structure exceedingly well marked. . . . . . This section also is about the middle of the Gault." The well in Bignor Park, mentioned by Martin in 1828 as 70 feet deep, was also most probably in these beds, though we have no details.

The upward limit of the Gault is very obscure, there being few exposures of the higher part. The only good section now visible is one noted by Mr. Lamplugh, in the road north of Sutton. The malm rock here seems to become more clayey downward and to pass into a rather sandy micaceous brown marl, which becomes more and more clayey below and merges into Gault. The clay about the junction has a brownish tint when weathered (and perhaps when fresh), and when dry has a whitish look. Lower down the clay is pale blue and very stiff, getting darker blue towards the base of the Gault. For proof that Upper Gault with *Ammonites rostratus* (Fig. 4) exists in West Sussex below the base of the malmstone we are indebted to Mr. Brydone, who found fossils in the marly clay forming the bed of the stream just below Duncton old church. These included *Ammonites rostratus, Belemnites minimus, Plicatula pectinoides, Pollicipes glaber?* and also the following among specimens sent to Mr. Jukes-Browne for identification: *Cardita tenuicosta, Nuculana vibrayeana*, and *Fusus*.

UPPER GREENSAND.

The earliest description of the Selbornian in Sussex was that by P. J. Martin in 1828. He divided it into *Galt* and *Malm*, subdividing the latter into "Greensand" and "Malm-rock."* He says, "This [chalk] marl passes into the malm, of which there is a thin stratum [*i.e.* Chloritic Marl], succeeded by a bed of greensand, and that by the more indurated malm rock, which again gradually resolves itself into the galt clay beneath."

Speaking of the bed which he specialises as "the greensand," he says "the best sections of this stratum are to be found at Steyning, Amberley, Bury, and Barlavington . . . . at Bury it is from 15 to 20 feet in thickness."

He continues thus:—"The great body of the malm rock next succeeds, advancing in a bold and broad talus [? terrace], at the foot of the chalk hills, and it is worthy of remark that it is broadest on the eastern side of every remarkable salient angle of the Chalk. . . . The wells are from 30 to 100 feet, and the average depth of the whole stratum may be about 70 or 80 feet. . . . . In its most indurated state the malm rock has a conchoidal fracture, and is of a bluish colour when fresh broken, but becoming white by exposure to air."

Though small exposures of the Upper Greensand are common, few of them call for special note. We will therefore merely mention the best that are met with when this rock is traced along its outcrop from west to east.

Elsted, according to Mr. C. E. Hawkins, is on the malm rock, which may dip to the north at about 5°. Sections of the sandy marl, which occurs at the base of the Upper Greensand, may be seen in the road-cutting leading down to Elsted Green, and also at the foot of the scarp north of Elsted; it is also exposed north of Didling. At Grayets a shallow well has been dug in this sandy marl, which is here sufficiently firm to stand without steining. The water in this well is held up by the underlying Gault clay.

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* Geological Memoir of a part of Western Sussex, p. 18.

The sections around Cocking are interesting, for just east of Sunwool Farm the passage from Greensand to Chalk is seen, glauconitic marl (base of the Chalk) passing down into soft glauconitic greensand. The beds below are also seen in various sections in the village; and Mr. Gould saw the lower beds well exposed in a drain at Sunwool Farm. The malm towards the bottom becomes a soft and rather sandy rock, with mica, ultimately passing rather suddenly into a marly clay, green mottled with red, which changes insensibly during the next 20 feet into Gault.

In the neighbourhood of Cocking, and perhaps continuously eastward to Beachy Head, a marked bed of dark-green glauconitic sand or sandstone occurs just below the junction with the Chalk. This sand is constantly exposed in the deep "hollow-ways" which descend the scarp; and though it usually contains only a poor fauna, its marked lithological character makes it a useful horizon and easy to trace. Many of the springs are given out at the junction of this bed with the malm rock, and not at the base of the malm rock.

At Graffham, a quarry south of Woodcut Farm shows 10 feet of massive malm rock, dappled with clayey streaks and containing pyrites. South-east of this quarry the junction of the Greensand with the Chalk can again be seen, though not clearly.

Near Barlavington, Sutton, and Bignor, where the outcrop turns southward, numerous exposures both of the greensand and malm-rock will be found, but neither the junction with the Gault below nor with the Chalk above is clear.

On the east side of the Arun a good exposure of the malm-rock will be seen in the river-cliff at Amberley; and south of Storrington this rock has been lately quarried for a new house. It will be noticed that in this part of the outcrop the springs are given out high up, apparently from a loose glauconitic sand only a few feet under the Chalk.

One other section within our area deserves special mention. A well made in 1844 at Gatehouse's brewery, Chichester, is said to have penetrated 84 feet of "Malm Rock containing Iron Stone Nodules," this rock being first reached at 970 feet below the surface, and 790 feet below the base of the Eocene deposits. It is difficult to understand this old section (which will be again referred to); but I cannot help doubting whether the Lower Chalk was really penetrated, and whether the so-called malm rock was not merely part of the Chalk Marl. The Chalk Marl along part of the escarpment of the South Downs is silty and micaceous, and might readily be taken for malm rock, when obtained blue and unweathered. If the Upper Greensand was really met within this well, the Chalk must be exceptionally thin. The new boring at Goodwood (see p. 32) leaves little doubt that the Chalk at Chichester must be more than 1,000 feet thick.

CHAPTER V.

CHALK.

More than a third of the area under consideration is occupied by Chalk, which forms the undulating hills known as the South Downs. These rise at their escarpment, which overlooks the Weald, to 700 or 800 feet above the sea, the highest points being found towards the west, where Linch Down touches 818 feet, and Duncton Down reaches 837 feet. The South Downs fall naturally into two divisions, separated by the transverse valley of the Arun. East of the Arun they are mainly bare and treeless; west of the Arun beech-wood and copse form a conspicuous feature. This difference, however, is probably due more to climatic than to geological causes, for as the area of high down becomes wider, the average height greater, and we travel westward into moister regions, the hills are more and more often capped with mists.

The Chalk out of which these hills are carved is of considerable thickness, being more than 1,000 feet at Goodwood Park, though a good deal of the upper part of the formation had been destroyed before the overlying Eocene strata were laid down. Though the whole of this thick mass would ordinarily be spoken of as "chalk," yet a cursory examination is sufficient to show that it falls naturally into three divisions—a white soft Upper Chalk with many flints, a white harder Middle Chalk without flints, and a grey marly Lower Chalk, which last shows trace of a division into firm greyish-white and grey chalk above and marl below. Besides these three lithological divisions, and some subordinate beds of varying texture and hardness, which will be described further on, the Chalk is divisible into a series of zones, each characterised by a peculiar assemblage of fossils, and these zones remain constant over wide areas, notwithstanding considerable lithological changes. Palæontological zones, however, have not hard and fast boundaries, but tend to merge one into another as the fauna changes slowly with the lapse of time. In this particular area no sudden breaks have been noticed in the Chalk or in its successive faunas. The zones now commonly recognised in Britain are as follows:—

Zone of	Ostrea lunata	Upper Chalk.
,,	Belemnitella mucronata	
,,	Actinocamax quadratus	
,,	Marsupites testudinarius	
,,	Micraster coranguinum	
,,	Micraster cortestudinarium	
,,	Holaster planus	
,,	Terebratulina	Middle Chalk.
,,	Rhynchonella Cuvieri	
,,	Holaster subglobosus	Lower Chalk.
,,	Ammonites varians	

The uppermost two of these zones, however, and the greater part of the next one, that of *Actinocamax quadratus*, are believed to be missing in this part of Sussex.*

LOWER CHALK.

On following the outcrop of the Lower Chalk from west to east, we find that it forms a belt of fairly uniform width throughout our district. This belt lies at the foot of the downs, or forms the lower and gentler slopes of the escarpment; it is undulating, marly and moist, forming excellent arable land, which changes into open down and sheep-pasture when the boundary of the Middle Chalk is passed. The change, however, does not coincide exactly with the geological boundary, for the large amount of wash and talus from the steeper hills above, tends to make the dryer soil of the Downs transgress some distance over the wetter Lower Chalk.

Owing to the wash from the hills above and other causes, continuous sections are seldom visible in our district, and it is difficult to obtain accurate measurements of the thickness. This difficulty is increased in another way, not usually taken into account, for it is impossible to place any reliance on the dips which can be measured. The general dip is southward; but nearly always the angle of the dip is increased by the weight of the hill above, which, pressing downward on the soft Lower Chalk, tends to tilt up its free edge, thus exaggerating the apparent amount of the dip. In the same way dips taken in soft deposits on a foreshore under high cliffs are never trustworthy; there is usually a tendency to dip inward toward the cliff. Making allowance for these uncertainties, the relation of the geological boundaries to the contour-lines suggests a thickness of 180 to 200 feet for the Lower Chalk, the deposit being apparently somewhat thicker in the east and south than in the west.

Along the western part of the outcrop of the Lower Chalk exposures are few, the old pits being much overgrown, and no clear section of either the top or the bottom of the division being now visible. Soft massive chalk seems to constitute the upper part, and marl more or less sandy and silty the lower part.

Around Cocking sections are clearer, and the basement beds are fairly well seen near Sunwool Farm, and in the road south of the village. Still further south there are several good sections in the massive grey chalk, which is worked for lime, and can also be seen around the spring at Crypt Farm. It appears as if this spring were given out at the junction of the grey chalk with the chalk marl below; but it may rise along a line of fault, for, at this point, there is an obscure disturbance, which may be either a small fault or one of the minor folds already mentioned.

The sections south of Heyshott are more satisfactory, road-cuttings and old quarries giving the following succession, though the exposures do not admit of accurate measurements:—

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* The information on the Chalk is taken largely from Mr. A. J. Jukes-Browne's Memoir on the Cretaceous Rocks of Britain, vols. ii. and iii. (*in the Press*).

Middle Chalk . . .	Melbourn Rock.
Lower Chalk . .	Belemnite marl. Coarse-grained chalk. Massive grey chalk. Chalk marl. Hard sandy glauconitic marl.
Greensand.	

The "coarse-grained chalk" was exposed in the roadway, but not seen in the quarries. The estimated thickness is here between 180 and 200 feet.

There are two quarries in the Lower Chalk south of Duncton Church. The lower of these is now disused and talused, but we are informed by Mr. R. M. Brydone that a good section of the Chalk marl was formerly exposed here, and that he obtained many fossils from it. He has kindly communicated the following information and list of fossils.

"The greater number of the fossils came from the lowest band in the pit, a bed of dark bluish-grey marl about 4 feet thick, soft when wet, but drying to a hard marl, and having a notably conchoidal fracture. *Brachiopoda, Serpulæ,* and *Onchotrochus* were especially abundant in this marl; other fossils were less common. Above this is about 10 feet of lighter grey chalk with few fossils, succeeded by a bed of very hard chalk mottled in light and dark grey, and containing many *Cephalopoda.*"

Fossils of the Lower Chalk.

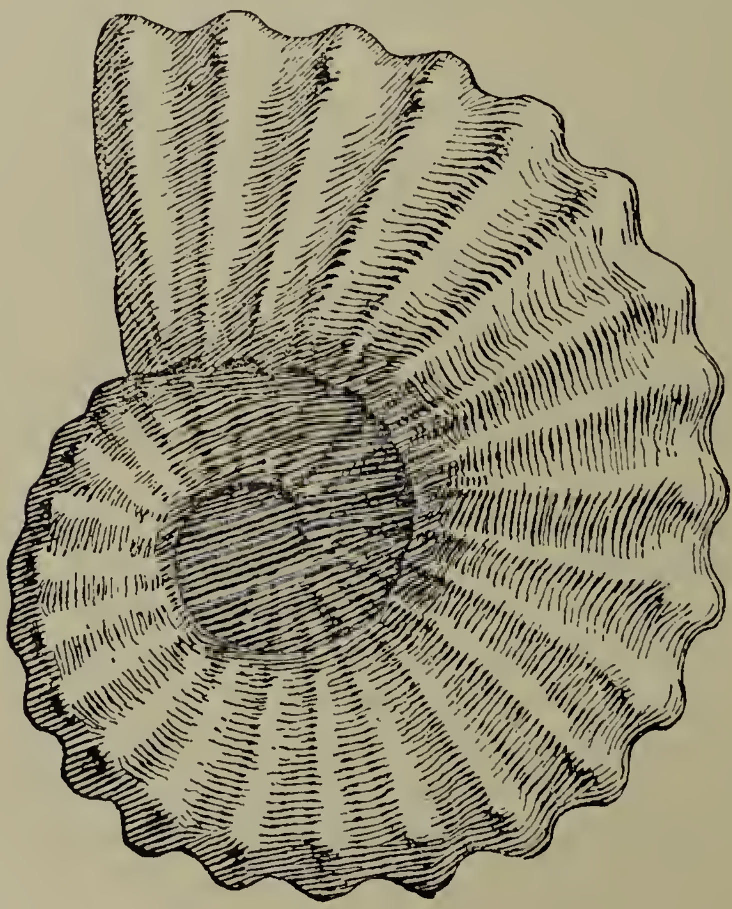

Fig. 6.

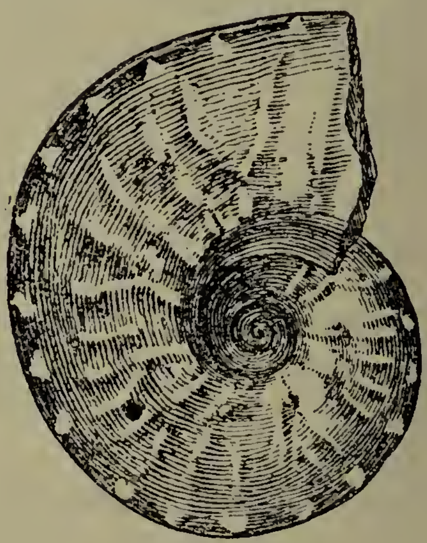

Fig. 7.

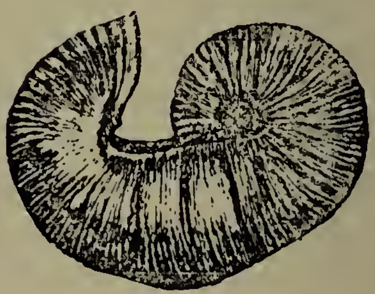

Fig. 8.

Fig. 6. Ammonites [Acanthoceras] rotomagensis, *Brong* ($\frac{1}{2}$ natural size).
Fig. 7. Ammonites [Schloenbachia] varians, *Sow.* ($\frac{3}{4}$ natural size).
Fig. 8. Scaphites æqualis, *Sow.*

The floor of the pit from which these fossils came is probably about 50 feet above the base of the Chalk.

A little to the eastward, and about 100 feet higher up the slope, is another quarry and limekiln where about 60 feet of chalk are shown, belonging to the zone of *Holaster subglobosus*. Mr. Brydone has here found the species noted below, but says that fossils, except *Ostreidæ*, were scarce.

FOSSILS OF THE LOWER CHALK.

	A. varians Zone. Duncton.	H. subglobosus Zone. Duncton.
Cimoliichthys lewesiensis, *Leidy*	—	x
Enchodus lewesiensis, *Mant.*	x	—
Lamna appendiculata, *Ag.*	x	x
Ammonites [Acanthoceras] navicularis, *Mant.*	x	—
„ „ rotomagensis, *Brongn.* (Fig. 6)	x	—
„ [Schloenbachia] varians, *Sow.* (Fig. 7)	x	—
„ „ Coupei, *Brongn.*	x	—
„ sp.	—	x
Baculites baculoides, *d'Orb*	x	—
Scaphites æqualis, *Sow.* (Fig. 8)	x	—
Turrilites tuberculatus, *Bosc.*	x	—
Nautilus elegans, *Sow.*	x	—
Cerithium ornatissimum ? *d'Orb*	x	x
Natica sp.	x	—
Pleurotomaria sp.	x	—
Solarium sp.	x	—
Exogyra haliotoidea, *Sow.*	—	x
Inoceramus striatus, *Sow.*	x	—
„ sp.	—	x
Lima elongata, *Sow.*	x	—
„ globosa, *Sow.*	x	x
Ostrea acutirostris, *Nilss.*	x	—
„ vesicularis, *Lam.*	x	—
Pecten Beaveri, *Sow.*	x	—
„ orbicularis, *Sow.*	x	x
„ (Neithea) 5-costata, *Sow.*	x	x
Plicatula inflata, *Sow.*	x	x
Magas Geinitzi, *Schloenb.*	x	—
Rhynchonella grasiana, *d'Orb.*	x	—
„ mantelliana, *Sow.*	x	—
„ Martini, *Mant.*	x	—
Terebratula squamosa ? *Mant.*	x	—
Terebratulina striata, *Wahl.*	x	x
Pollicipes sp.	x	—
Serpula ampullacea, *Sow.*	x	x
„ annulata, *Reuss*	x	—
„ macropus, *Sow.*	x	x
„ umbonata, *Sow.*	x	—
„ plexus, *Sow.*	x	—
„ „ var. gordialis, *Schloth.*	x	—
Echinocyphus difficilis, *Ag.*	—	x
Holaster sp.	—	x
Pentacrinus sp.	—	x
Onchotrochus serpentinus, *Dunc.*	x	—

Again, in the lane leading up West Burton Hill, Mr. W. Hill saw beds of greyish-white chalk alternating with beds of marly chalk; *Ammonites varians* and *Am. Mantelli* occurred frequently at a spot considerably more than 100 feet above the base of the Chalk. Ascending the lane these beds give way to more massive lighter coloured chalk, and the top of the Lower Chalk is reached a little to the north of the tumuli, but there is no clear section, and the Belemnite Marls were not seen.

Immediately south of Bury some glauconitic sandy marl, seen in the roads to Bury Hill and to Houghton, must be very near the base of the Chalk. The middle of the Lower Chalk is not exposed; but a quarry at the foot of Bury Hill shows an excellent section of grey chalk, passing upwards into the "Belemnite marl" (here about 10 feet thick), which again is capped by Melbourn Rock. The characteristic belemnite of this marl (*Actinocamax plenus*) does not appear yet to have been found at this locality, and throughout our area the Belemnite marl is sparingly fossiliferous. At Bury the southward trend of the escarpment causes the level of the base of the chalk to sink rapidly, so that near Houghton the whole of the Lower Chalk is lost beneath the sea-level. This trenching of the Downs by a transverse valley, and the consequent change of direction of the geological boundaries, enables us to calculate the dip, which here appears to be about 4°, almost due south.

A curious point, not exactly geological though connected with geology, may be referred to in connection with the area just described. Some parts of the slopes are too steep for cultivation and are clothed, and seem always to have been clothed, with ancient hanging woods, locally known as "hangers," principally of beech, with some undergrowth of holly and hazel. So little of the primæval forest is anywhere left in Sussex, except on the heavy clay lands of the Weald, that it is interesting to find these small outliers still remaining. They contain rare woodland animals and plants such as one does not find in the forests of the Weald. Among the mollusca, both *Helix obvoluta* and *Clausilia Rolphii* are to be found, and among the plants Solomon's seal, and herb Paris. In one of these woods the zig-zag connecting the Roman Stone Street with the lowlands is well seen.

East of the Arun sections are more frequent, and there is less woodland and copse over the Lower Chalk. Though the actual base is not seen near Amberley, the railway cutting near the village shows some beds not much above. They consist of hard, bluish marl with small grains of glauconite and flakes of mica. The south end of this cutting is much overgrown, but shows sandy marl, which seems to mark the junction with the grey chalk above. The next few feet cannot be examined, but a quarry near by continues the succession, probably nearly up to the Belemnite marl; it is thus described by Mr. W. Hill: "Mr. Pepper's quarry, about a quarter of a mile north of Amberley Station, is about 80 feet deep; 60 feet of this is in massive smooth white chalk, passing down into greyer chalk, the lowest 10 or 12 feet being in courses divided by marly bands. In the floor of the quarry a narrow working disclosed about 20 feet more of grey chalk and grey marl in alternating courses. No fossils were seen, nor did the quarrymen possess any."

Between Amberley and Sullington Hill a grey siliceous chalk appears at various places, apparently on the same horizon as the sandy bed seen in Amberley cutting. In the road to the Downs from Amberley village this bed is a hard fine-grained calcareous sandstone with *Pecten*, and makes a noticeable feature, which has been traced eastward to the limit of our district. Near this limit a series of sections will be found, those below Chantry Hill and Sullington Hill being particularly good. At Chantry Hill the junction of the Middle and Lower Chalk can be seen. At Chantry Farm the road-cutting, probably about 30 feet up in the Chalk, shows fine-grained grey gritty marl, full of small brachiopods, among which Dr. Kitchin identified *Kingena lima*, *Rhynchonella grasiana*, *R. mantelliana*, *R. martini*, *Terebratula semiglobosa* ?, *T. squamosa*, *Terebratulina striata*, and also *Serpula umbonata*. Above this comes grey marl or marly chalk, but the sections are obscure till the Belemnite marl and the Melbourn rock are reached. The total thickness of the Lower Chalk seems here to be 200 feet.

MIDDLE CHALK.

This division consists of hard white irregularly bedded chalk, full of fragments of *Inoceramus*, but not usually yielding many other fossils. At its base it becomes still harder and more rocky, forming the Melbourn Rock, which, however, though sharply distinguished from the Belemnite marl below gradually merges upwards into Middle Chalk of the usual type. The thickness of the Melbourn Rock is about 10 or 15 feet; the total thickness of the Middle Chalk about 200 feet.

The Middle Chalk occupies a great part of the steep face of the escarpment of the Downs, its outcrop is also continued in a long spur through the middle of the Downs, from Upper Waltham to West Dean, and it reappears also as inliers in the valleys at Binderton and Stoughton. Notwithstanding this considerable exposure, good sections are not very common, most of our knowledge being derived from the large pits at Amberley and Houghton. We will trace this division also from west to east along the escarpment; afterwards describing the exposures in the interior of the Downs. The hard Melbourn Rock, resting on the exceptionally soft Belemnite marl, tends to make a distinct ledge or terrace in the face of the escarpment, especially in the eastern part of our area, where the difference in hardness is strongly marked. Towards the west this ledge is not so striking a feature, though there is seldom much difficulty in fixing exactly the position of the base of the Middle Chalk. Its upper limit, however, is much more difficult to define; for the Chalk Rock, which over wide areas divides the Middle from the Upper Chalk, is non-existent in this district, and a boundary has to be drawn at or near the level on which the first regular bed of flints makes its appearance. The fossils of the Chalk Rock, which can sometimes be found occupying a narrow zone even where the rock itself is missing, have not been recognised in our area.

In the escarpment near Treyford the Melbourn Rock does not seem to be noticeably different from the rest of the Middle Chalk; but there are no clear sections. The higher part of the division, however, is visible in the road-cuttings and pit east of Buriton Farm, where a few grey flints extend down into the Middle Chalk. The Chalk Rock was not recognized in the pit, but perhaps its fossils might be found there with longer search.

Below Linch Down hard chalk with *Inoceramus* is seen in the road-cutting; but neither top nor bottom of the Middle Chalk is quite satisfactorily defined. A mile to the east, however, the Melbourn Rock runs out in a bold spur on Bepton Down, and the transition from flintless to flinty chalk is also easy to trace in the road 200 feet higher. Here F. Sargent observed 3 or 4 inches of fuller's earth in the Chalk (*Geol. Trans.*, vol. i., p. 168).

At Cocking the Melbourn Rock makes a clear, well-defined feature, and the railway-cutting south of the tunnel shows an excellent section of the junction of the Middle with the Upper Chalk. A thin hard bed in the road to Cocking (West) Down may represent the true Chalk Rock; but this seam could not be found in the railway cutting. The Chalk Rock should appear also in the old pits and cuttings at the west edge of Cocking (East) Down, where chalk with thick-skinned black and grey flints seems to pass down into hard flintless chalk with *Inoceramus*; however, it could not be found.

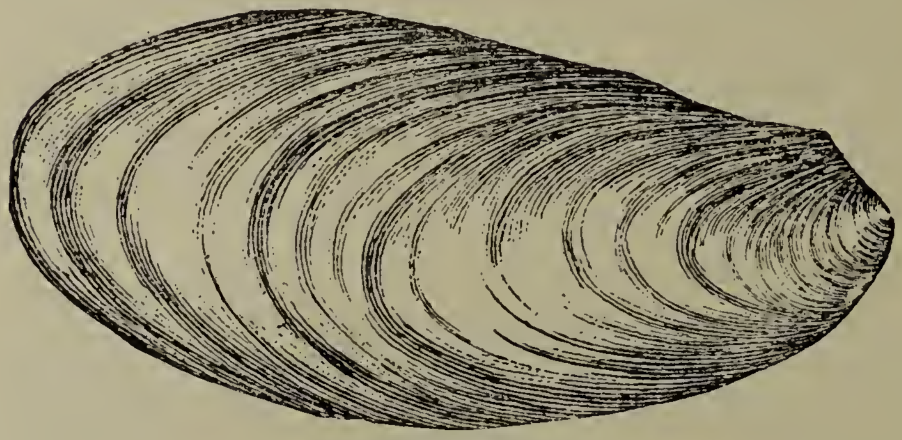

Fig. 9.

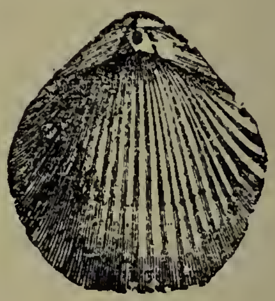

Fig. 10.

Fig. 9. Inoceramus mytiloides, *Mant* (half natural size.)
Fig. 10. Rhynchonella Cuvieri, *d'Orb*, (twice natural size.)

The next sections of interest are met with at Graffham, where, in the roads leading to the Downs and in the pit near by, the hard Melbourn Rock is well seen, while the gradual passage into flinty chalk can be traced in the roads 200 feet above. Here also no rock of exceptional hardness could be found at the junction with the Upper Chalk.

Barlavington Downs is one of the best places for examining the Middle Chalk; for the division has there an exceptionally wide outcrop, and pits expose a considerable part of the thickness. The cutting on the high road to Chichester exposes the Melbourn Rock, resting on Belemnite marl. A pit immediately above shows 40 feet of rough nodular chalk, which belongs to the zone of *Rhynchonella Cuvieri* (Fig. 10), that fossil and *Inoceramus mytiloides* (Fig. 9) being abundant. Another pit, in Duncton Hanger, which is a quarter of a mile south-east of

Duncton Church, exposes 90 feet of this chalk, including the top of the Melbourn Rock. A third pit, higher up and on the west side of the Chichester road, perhaps exhibits the junction with the Upper Chalk; but, unfortunately, the lower part of this pit is hidden by talus, and I am not sure that the Middle Chalk has been reached.

The best sections in our district are those in the large chalk-pits of Bury and Amberley. On the road from Bury to Arundel two pits will be found; the lower one showing Melbourn Rock resting on Lower Chalk, the higher showing hard chalk with marl seams and a few scattered flints. The upper pit seems nearly to reach the Chalk Rock. The shallow road-cutting above Houghton village shows a thin hard bed which may be the true Chalk Rock.

Rough nodular chalk which cannot be far above the Melbourn Rock is exposed in the most northern part of the large quarry by Amberley station, close to the main road. About 25 or 30 feet of this chalk is seen, and from it Mr. Hill obtained *Inoceramus mytiloides* and a few *Rhynchonella Cuvieri.*

The best section of the zone of *Terebratulina* in western Sussex is that in the large quarry by Amberley station. Writing of this quarry Dixon said:* "The large quarry on the opposite side of the River Arun (to Houghton) is called Balcombe-pit, and is of the Lower Chalk formation, or that without flints." Among fossils found here he mentions *Radiolites*, "bones of turtles and fishes in very good preservation, particularly *Beryx ornatus* and *Macropoma Mantelli*, Echinoderms and Crustaceans, especially *Enoploclytia Leachi.* The nodules of sulphide of iron here often contain a *Terebratula* or other small shell in the centre, which elsewhere is rare."

Professor Barrois has also described this pit, giving the following particulars†:—

	Feet.
5. Compact chalk with scattered flints.	
4. Shaly chalk with scattered grey flints, *Terebratula semiglobosa, Inoceramus sp.* - - - - - - - -	6½
3. Layer of yellowish nodules.	
2. Homogeneous white chalk, in courses separated by seams of grey marl - - - - - - - - - -	82
1. Hard compact white chalk, in beds about 3 feet thick separated by marly seams, which contain nodules (of chalk) - - - - - - - - -	33
	About 121

Mr. W. Hill visited the quarry in 1897, and contributes the following note: Here about 110 feet of Turonian Chalk is traversed; about a third of the main face is now obscured by talus, but smaller cuttings to the right and left expose the lower parts. The chalk is for the most part soft and white; flints occur near the top, and there is at least one layer of large, massive flints. *Terebratulina gracilis* var. *lata* is fairly common, *Spondylus spinosus* and *Sp. latus* (?) also occurred, and in a fallen block containing some of the large flints a crushed Echinoderm, apparently *Holaster planus*, was found.

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* Geology of Sussex, Second Edition. 1878, p. 130.

† Recherches sur la Craie d'Angleterre et de l'Irlande, p. 33.

Mr. Jukes-Browne has compiled the following list of Middle Chalk fossils from Amberley and Houghton:—

	Zone of Rhynch. Cuvieri.	Zone of Tereb. gracilis.	Zone unknown.
Pisces.			
Beryx, see Ctenothrissa and Hoplopteryx			
Corax maximus, *Dixon*	—	—	x
Ctenothrissa radians, *Ag.*	x		
Enchodus lewesiensis, *Mant.*	—	—	x
Hoplopteryx lewesiensis, *Mant.* (ornatus, *Ag.*)	—	—	x
Lamna appendiculata, *Ag.*	x		
Oxyrhina Mantelli, *Ag.*	—	x	
Lamellibranchiata.			
Inoceramus Brongniarti, *Sow.*	—	x	
„ mytiloides, *Sow.*	x		
Ostrea semiplana, *Sow.*	x		
Plicatula sigillina, *Woodw.*	—	—	x
Radiolites Mortoni, *Mant.*	—	—	x
Spondylus latus, *Sow.*	—	x	
„ spinosus, *Sow.*	—	x	
Brachiopoda.			
Rhynchonella Cuvieri, *d'Orb.*	x	x	
Terebratulina gracilis, *Schloth.* var lata, *Eth.*	—	x	
„ striata, *Wahl.*	—	x	
Terebratula semiglobosa, *Sow.*	x	x	
Crustacea.			
Enoploclytia Leachi, *Mant.*	—	x	
Echinodermata.			
Galerites subrotundatus, *Mant.*	—	x	
Holaster planus, *Mant.*	—	x	

The sections in the escarpment east of Amberley call for no remark.

On returning westward to Bignor and Barlavington we find a break in the escarpment, and a pass connecting with the Lavant valley, through which the high-road to Chichester is carried. For a considerable part of its course this valley nearly coincides with an anticline, which brings up the Middle Chalk all the way to West Dean. The sections in the upper part of this valley are poor; but there are doubtful indications of the hard Chalk Rock in the road west of Upper Waltham and in that north of East Dean. In the exposure at East Dean chalk with flints can be seen immediately above, and chalk without flints can be traced down to the village. More than half the thickness of the Middle Chalk must here be cut through by the valley. A pit on the south side of the valley, above Manor Farm, shows a section which may be entirely in Middle Chalk or may show the junction with the Upper Chalk. I do not think, however that the very hard chalk is the Chalk Rock. The measurements are:—

	Feet.
Chalk with marl seams - - - - - - - - -	15
Very hard chalk - - - - - - - - - -	2
Chalk with marl and a seam of gray flints - - - -	5

The railway cuttings near Singleton and West Dean showed excellent sections of the hard chalk without flints; but none of them seem to reach beds more than 100 feet down in the Middle Chalk. A pit by the road side north-west of the Station shows 25 feet of hard chalk, and a few feet above flinty chalk crops out in the road. Another pit, on the road to Chilgrove, exposes a characteristic section of the upper part of the division:—

	Ft.	In.
Hard rubbly chalk - - - - - - - -	6	0
Grey clay - - - - - - - - - -	0	2
Hard chalk - - - - - - - - -	2	0
Tabular flints - - - - - - - - -	0	2
Hard chalk - - - - - - - -	7	0

Still lower there is hard chalk with a few flints, and it may be observed that as we travel westward, or perhaps rather south-westward, there is a noticeable tendency of flints to become more common and to extend further down into the Middle Chalk. The occurrence of tabular flint in this division is, however, unusual; but just beyond our limits, in the bottom of the valley west of Bow Hill, a thin tabular flint was noticed more than 100 feet down in the Middle Chalk. A pit about 100 feet above, and at the west end of Lambdown Hill, shows hard nodular chalk with a line of grey flints at the top, whilst the road between exposes only hard chalk without flints.

The Middle Chalk has also been reached in two wells, the one at Chichester, the other at Goodwood. The well at Gatehouse's Brewery in Chichester was made so long ago (1844) that the record is not easy to interpret. It can only be suggested that the 4-foot bed met with 600 feet down in the chalk and described as "crystallised carbonate of lime" represents the Chalk Rock, which is often markedly crystalline. A small fragment which happened to be preserved, shows it to be a very hard crystalline chalk.

UPPER CHALK.

The greater part of the Downs is carved in the flinty Upper Chalk, which reaches a thickness of 600 feet, though several hundred feet of the upper strata, represented in adjoining counties, are here missing. The whole of the zone of *Belemnitella mucronata* and probably great part of that of *Actinocamax quadratus* are absent. Much, however, remains to be done before the palæontological divisions in this area can be considered as thoroughly known; at present our knowledge of the fossils is confined mainly to the valley of the Arun, and to the disturbed chalk of Highdown Hill. The following account of the Upper

Chalk of the Arun Valley is by Mr. Jukes-Browne (from notes taken by Mr. W. Hill and Mr. R. M. Brydone) :—

No good sections of the zone of *Holaster planus* (Fig. 13) were found near Amberley, but it is traversed by the cutting for the railway about half a mile south of the station, at the east end of a short tunnel. The chalk here is lumpy and of a creamy-yellow tint; no continuous section can be taken, but *Micrasters* are very numerous, and are all of the varieties termed "low-zonal" by Dr. A. W. Rowe; they are associated with *Echinocorys scutatus* (Fig. 14), *Rhynchonella plicatilis*, *Rh. reedensis*, *Terebratula carnea*, etc. These beds probably belong to the upper part of the *Holaster planus* zone.

Higher beds, including the greater part of the *M. cortestudinarium* zone, with part of the overlying *M. coranguinum* zone,

FOSSILS OF THE UPPER CHALK.

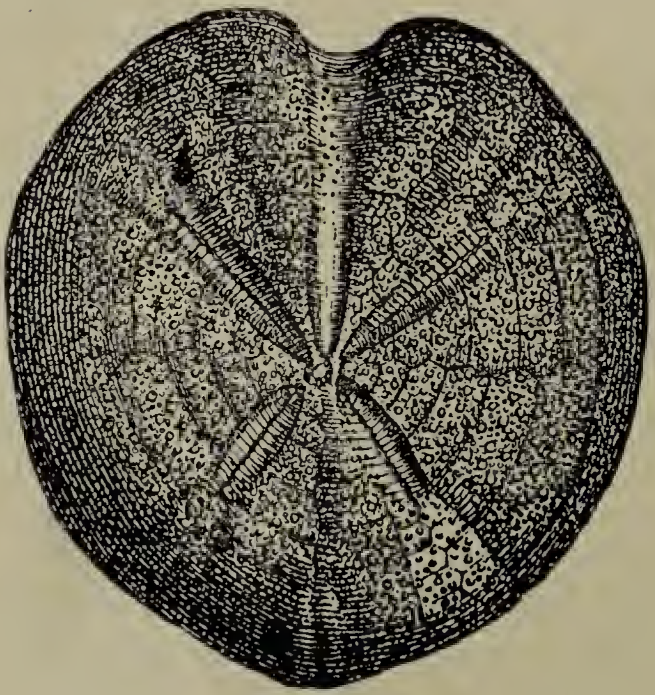

FIG. 11

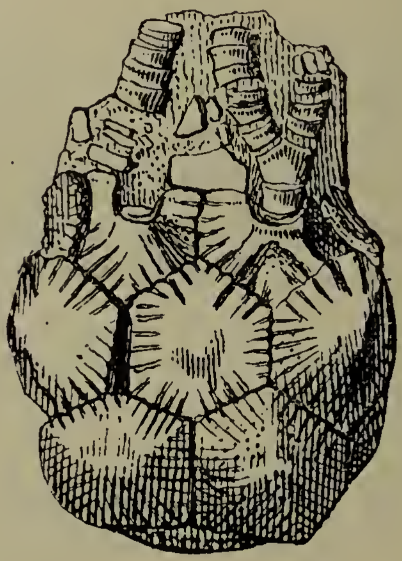

FIG. 12.

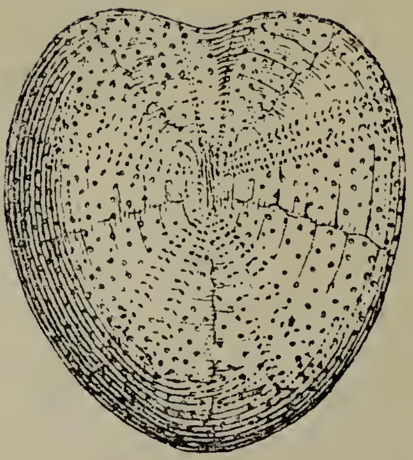

FIG. 13.

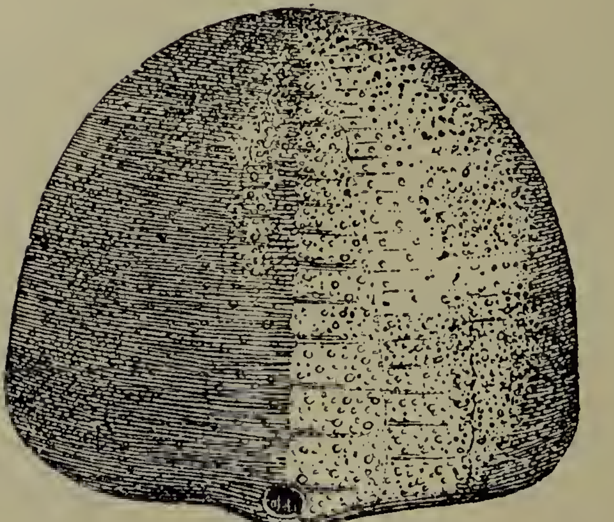

FIG. 14.

FIG. 11. Micraster coranguinum, *Leske*.
FIG. 12. Marsupites testudinarius, *Schloth.*
FIG. 13. Holaster planus, *Mant.*
FIG. 14. Echinocorys scutatus, *Leske*. (Three-quarters natural size.)

are exposed in the large quarry south-west of Houghton. The section here is given below. Mr. Rhodes obtained *Micraster cortestudinarium, M. præcursor, Holaster planus, Rhynchonella plicatilis* and *Lima Hoperi* from a bed of "greyish chalk" in this quarry.

Parts of these higher zones are exposed also in the quarry on Duncton Hill, about two-thirds of a mile south-west of Duncton church. The lower part was found to be obscured by *talus*, but the face above this exposed about 2 feet of hard nodular chalk, surmounted by 20 feet of chalk, with many flints, which are grey inside. This probably includes the junction of the zones of *H. planus* and *M. cortestudinarium.*

We are indebted to Mr. R. M. Brydone, for the following list of fossils which he has found in this quarry:—

Ostrea vesicularis.
Exogyra haliotoidea.
Inoceramus sp.
Plicatula Barroisi.
Terebratula semiglobosa.
Rhynchonella plicatilis.
,, reedensis.
Cidaris clavigera.
Cyphosoma sp.
Echinocorys gibbus.
Holaster planus.
Micraster sp.
Pentacrinus sp.

The lower part of the *M. coranguinum* zone and its junction with the *M. cortestudinarium* zone are exposed in the large quarry south-west of Houghton. The section here was taken by Mr. William Hill in 1897, and is as follows:—

		Ft.	In
	Chalk with layers of flints (inaccessible) - - - - (?)	50	0
	Seam of flint, nearly continuous, but breaking here and there into nodules - - - - - - - - - -	0	2
	Rather hard white chalk with scattered flints, yielded a typical *Micraster coranguinum* (Fig. 11) - - -	10	0
	Continuous seam of flint - - - - - - - - - -	0	3
	Rather soft white chalk with a few scattered flints near the base - - - - - - - - - - - -	5	0
	Soft mealy chalk, with lumps of hard yellowish compact chalk, with many Micrasters and other fossils - -	1	6
	Thin seam of marl - - - - - - - - - -	0	1
	A massive bed of firm white chalk, with a few scattered flints near the base - - - - - - - -	3	0
	Massive bed of rough lumpy chalk, hard creamy yellow lumps cemented together in a matrix of lighter colour, the whole course being hard - - - - - - -	3	3
Zone of *M. cortestudinarium.*	Continuous seam of flint - - - - - -	0	2
	Hard white chalk veined with grey - - -	2	6
	A conspicuous layer of large flints - - - -	0	8
	Smooth and firm white chalk, rather broken up where measurements were taken, forming a sort of ledge in this part of the quarry - - -	4	6
	Massive firm white chalk without flints - - - -	3	6
	Massive firm white chalk, with flints both scattered and in layers; no fossils seen - about	50	0
	About - - - - - - - - -	134	0

Owing to the scarcity of fossils the exact limit-plane between the zones cannot be determined, and it is possible that it should be taken rather higher up than we have placed it.

Other pits to the southward show white chalk with layers of black flints, featureless, but unquestionably belonging to the zone of *M. coranguinum.* From one half a mile west of South Stoke Mr. Rhodes obtained *Septifer* (*Modiola*) *lineatus*, *Micraster coranguinum* and *Ventriculites cribrosus.*

A large quarry at the back of the Black Rabbit Inn appears to show the junction of the *M. coranguinum* and *Marsupites* zones. Mr. Hill reports that the lower 60 or 70 feet here exposed consists of firm chalk with many layers of black flints; the upper 50 feet shows soft chalk with few flints; only a few sparsely scattered nodules or in lines at distant intervals.

Similar chalk with few flints is seen in the river-cliff at Burpham, on the eastern side of the valley. This was searched by Mr. Rhodes, who found *Marsupites* (Fig. 10) in a band, which is first seen about 50 feet above the river, but comes down to the water-level further south. About 15 feet above this band he found a bed of oysters like that at Burwells Farm, Lancing. Near the top of the cliff he noticed a layer of lumpy yellow-stained chalk, containing some *Serpula, Bryozoa,* and decomposed Sponges.

The section is continued in a pit by the high road west-north-west of Warningcamp Hill, of which pit Mr. Rhodes made the following note:—"About 10 feet above the floor of the pit is a bed of stained chalk, containing rotted sponges, *Serpula,* and a layer of flint nodules, which seems to be the same as that seen at the top of Burpham Cliff. Above this is chalk with few flints, and about 22 feet above the floor is a 4-inch layer of marl, succeeded by chalk with marly layers, for 12 feet, in which *Offaster pillula* is common." This may be regarded as the base of the *Act. quadratus* zone. The large pit on Warningcamp Hill shows chalk with some thin flint floors and frequent layers of flint nodules, and is probably in the *Act. quadratus* zone, though its base may be in the lower zone, as Mr. Rhodes found a *Marsupites* plate here. By the side of a small stream west of Arundel is a pit in chalk with layers of black flints, probably in the *Act. quadratus* zone, though no *Belemnite* was found.

The list of fossils collected by Mr. Rhodes from the quarries above mentioned is given on p. 32.

In the hope of finding softer water in the Lower Greensand than that obtained from the Upper Chalk, an old well near the Kennels at Goodwood has been deepened recently, and the boring has reached a depth of no less than 1,012 feet without penetrating the Chalk. As the Goodwood boring gives the only nearly complete measurable section through the Chalk of West Sussex, details are given below, as far as they can be ascertained. Unfortunately, at the time of my visit in December, 1902, the large cores had been exposed to the weather for several months, and the figures denoting depths had all disappeared. Only one core, from within 7 feet of the lowest point, could be identified. It has only been possible, under these circumstances, to draw up a section from details and small samples communicated by the well-sinkers, Messrs. Le Grand and Sutcliff, and from some additional information obtained on the spot, through the Hon. W. F. Dundas.

The well is situated half a mile north-west of Goodwood House, and is almost on the 200-feet contour line. It is distant about a mile and a-half from any Eocene strata, and some part of the Upper Chalk may therefore be missing. Probably the thickness of the missing Chalk, seen further south, does not exceed 200 feet; this would make the total thickness of the Chalk in West Sussex somewhere about 1,200 feet. Possibly the lateral pressure which formed the Chichester syncline may have slightly increased the apparent thickness of the softer parts of the Chalk, for the Lower Chalk is decidedly thicker than would have been expected at this point. The lowest bed reached would appear, from its lithological character, to be close to the base of the Chalk, and probably within ten feet of the Upper Greensand.

The particulars of this well are as follows, notes in square brackets referring to specimens examined:—

		Thickness. Feet.	Depth. Feet.
Upper Chalk.	Old dug well	0	134½
	Old boring (11-inch) shelled out in chalk with flints	0	412
	Chalk and flints	5	417
	" " " free cutting, and water	22½	439½
	Very hard chalk	¾	440¼
	Chalk and flints	19¾	460
	" " " hard	12	472
	" " "	26	498
	" " " very hard	13	511
	" " "	43	554
	" " " very hard	5	559
	Sticky chalk and flints	7	566
	Chalk and flints, very hard	8	574
Chalk Rock?	Hard rock chalk	12	586
	Softer chalk	2½	588½
	Hard rock chalk	9	597½
Middle Chalk.	Softer chalk	6½	604
	Hard "	31	635
	Softer "	2½	637½
	Hard "	16	653½
	Very hard chalk	4½	658
	Hard "	32	690
	Very hard "	2	692
	Hard "	5½	697½
	Very hard "	2½	700
	Hard "	110	810
Lower Chalk.	Grey " [fish scales and pyrites at 823½ ft.]	13½	823½
	Hard grey " [fish scales, pyrites, and a little mica at 889 ft. [Alternating grey chalk and soft grey marly chalk]	178½	1002
	[Darker grey hard rock with *Serpula plexus* and much insoluble residue of flinty silica, quartz, mica, and a little glauconite at 1,002 ft. [Lighter-grey hard rock with numerous fucoid-like impressions.]	10	1012

Between 445 and 500 feet a spring was met with in the Upper Chalk. It yielded over 40 gallons per minute, pumping 8 hours a day. No water was found below this spring, and the boring was abandoned at 1,012 feet.

———	Houghton.	Burpham.	Warningcamp.	Warningcamp Hill.	Arundel.
Ctenothrissa	—	x	—	—	—
Fish vertebræ	—	—	—	x	—
Inoceramus sp.	x	x	x	x	—
Lima Hoperi, *Sow.*	x	—	—	—	—
Ostrea acutirostris, *Nilss.*	—	x	—	—	—
„ normaniana, *d'Orb.*	—	x	—	—	—
„ semiplana, *Mant.*	—	—	—	x	—
„ vesicularis, *Lam.*	x	x	—	x	-
Pecten (Chlamys) cretosus *Defr.* = nitidus, *Mant.*	—	—	x	x	—
„ (Neithea) quadricostatus, *Sow.*	—	x	—	—	—
„ „ quinquecostatus, *Sow.*	—	x	—	x	x
Spondylus dutempleanus, *d'Orb.*	—	x	—	—	—
„ spinosus, *Sow.*	x	x	—	—	—
„ striatus ? *Sow.*	—	—	x	x	x
Crania sp.	—	x	—	—	—
Kingena lima, *Defr.*	—	x	—	—	—
Rhynchonella limbata, *Schloth.*	x	x	?	x	x
„ plicatilis, *Sow.*	x	x	—	—	—
Terebratula biplicata ? *Sow.*	x	—	—	—	—
„ semiglobosa, *Sow*	x	—	—	x	—
Terebratulina Rowei, *Kitch.*	—	x	—	—	—
„ striata, *Wahl.*	—	x	—	—	—
Alecto sp.	x	x	—	—	—
Bidiastopora sp.	—	x	—	—	—
Bernicea papillosa, *Reuss*	x	—	—	—	—
„ sp.	—	x	—	—	—
Entalophora obliqua ? *d'Orb.*	—	—	—	—	x
„ sp.	—	x	—	x	—
Eschara sp.	—	x	—	—	x
Escharina sp.	—	x	—	x	x
Idmonea sp.	—	—	—	x	—
Pustulipora (Hammia) pustulosa, *Goldf.*	—	x	—	—	—
Semieschara sp.	—	—	—	x	x
Pollicipes sp.	—	—	—	x	—
Serpula ampullacea, *Sow.*	—	—	—	—	x
„ plexus, *Sow.*	x	x	x	—	—
„ pusilla, *Sow.*	—	—	—	—	x
„ turbinella *Sow.*	—	—	—	x	x
Terebella lewesiensis, *Davies*	—	—	—	—	x
Bourgueticrinus ellipticus, *Goldf.*	—	x	—	—	x
Cidaris (spines)	—	—	—	x	x
Echinocorys scutatus, *Leske*	x	x	x	x	—
Galerites (= Echinoconus)	—	x	—	—	—
Goniaster (ossicles)	—	x	—	x	—
Marsupites testudinarius, *Schloth.*	—	x	—	x	—
Micraster coranguinum, *Klein*	x	?	—	—	—
„ sp.	x	—	—	—	—
Offaster pillula, *Lam.*	—	x	x	—	—
Parasmilia sp.	—	x	—	—	—
Porosphæra globularis, *Phil.*	—	x	x	—	x
„ urceolata, *Phil.*	—	—	—	x	—
„ Woodwardi, *Carter*	—	x	x	x	—
Callodictyon sp.	—	x	x	—	—
Placotrema cretaceum, *Hinde*	x	—	—	—	—
Ventriculites cribrosus, *Phil.*	x	—	x	—	—
„ impressus, *Smith*	x	x	—	—	—
„ sp.	—	—	—	—	x

CHAPTER VI.

EOCENE.

Eocene deposits occupy the southern part of our area, crossing it in a sharp synclinal fold, which runs east and west, being bounded on each side by the Chalk. Over the greater part of this region, however, the geological structure is somewhat obscure, and could only be worked out by piecing together every scrap of evidence, from ditch-sections to the numerous well-borings. The reason of this obscurity is that the greater part of the highly inclined Eocene and Cretaceous deposits were afterwards planed down to a nearly level surface, over which gravel has been spread, completely hiding the underlying rock, and suggesting anything rather than an area of high dips and exceptional disturbance. The only part of this region that suggests disturbance, and that yields clear surface evidence, is the extreme east, where the Eocene strata can be seen to lie in a trough or basin which separates Highdown Hill from the main mass of the Downs.

Reading Beds.

The Reading Beds between Highdown and Chichester are exceptionally uniform in character and in thickness. They consist almost entirely of stiff red-mottled clay, with a few flints at the base. The thickness is everywhere about 100 feet. No fossils have yet been found within our area, the nearest being two or three obscure marine shells discovered at Lancing, close to the base of the deposit. It is not uncommon in the Hampshire Basin for a little glauconitic sand with marine fossils to occur near the bottom of the Reading Beds; but in this particular district nothing of the sort has yet been noticed, even in continuous borings which penetrate to the Chalk. The red-mottled clays, which are here the only representatives of the period, seem to be of lacustrine origin; but it is unusual to find fossils in clays of this character.

At the time when the Survey was being made no pits were open in the Reading Beds near Highdown Hill, though abundant indications of the presence of the characteristic red-mottled plastic clay were discovered in the ditches. A well at Patching, communicated by Messrs. Duke & Ockenden, shows that these clays are at least 67 feet thick. Another well, at the Decoy Cottage, close to the ponds in Angmering, is said to have penetrated 149 feet of clay before reaching the Chalk; but no details could be obtained, and it is doubtful how much of this clay may belong to the London Clay. The upper part of the red-mottled clay can still be seen in the railway-cutting close to Arundel Station, though the section is much overgrown and obscured by landslips. A boring in the Station showed at least 88 feet of the clay, Chalk being reached, according to Messrs. Duke & Ockenden, at 106 feet from the surface. The upper beds in this boring, described as London Clay, may be marsh clay of the Arun.

Three small pits near Arundel were the first clear sections met with in travelling westward. The brickyard near the Gas Works showed 5 feet of red-mottled clay, and a small pit at the edge of the wood, east of Park Farm, exposed 7 feet of similar clay. In each of these cases the pit is in the lower half of the mass. Another pit at the north end of Tortington Common was in somewhat higher beds, but the character was the same.

West of Brinsted few clear sections are to be seen, though the Reading Beds occupy a wide area beneath the Drift. Various borings, however, penetrate to the Chalk. One of these, at Barnham Junction, shows a thickness of 108 feet of red and mottled clays, with a bed of flints a foot thick at the base. Another section, at Walberton Brewery, was communicated by Messrs. Ellis & Sons, who had also preserved a series of samples. As this gives a good idea of the general character of the deposits the details are here quoted; but the London Clay should probably be thicker, and the Reading Beds thinner, than is given. Unfortunately the first numbered sample was from 128 feet:—

		Feet
Drift.	Loamy sand	about 20
London Clay.	Blue clay	about 30
Reading Beds.	Mottled clay, at about 50 feet (sample not labelled and doubtful). Red clay at 128 and 146 feet. Lignite and black clay, a thin bed between 150 and 160 feet. Grey clay, at 170 feet. Red clay, at 171, 171 and 173 feet. Hard grey sand, at 174 and 176 feet. Mottled sand and clay, at 183, and 185 feet. Red clay, at 187, 190, and 192 feet. Dark mottled clay, at 193, 194, 196, and 197 feet. Hard bed, at 198 feet.	148
Chalk		115

At Westhampnett the Brick Works, which lie in a shallow valley, cut through the Drift, and show a section of 13 feet of mottled red, blue and black clays. Several of these valleys around Chichester show indications of the same clay; but the only other pit is found at Fishbourne. Borings at Chichester and at Fishbourne prove, however, the total thickness of the Reading Beds; which in the former case are 97 feet, in the latter either 98½ or 106½, the uppermost 8 feet, described as light-grey clay, perhaps representing the base of the London Clay.

London Clay.

The London Clay of our area consists of dark-blue or grey clay with occasional septarian nodules, alternating, especially in the lower part, with beds of fine-grained sandy loam, or even of sand. These in one or two places apparently become hardened into a rock like that which forms Bognor Ledge. At the base of the London Clay there are usually a few perfectly rounded flint-pebbles, this seam becoming of sufficient thickness around Clapham to be dug for gravel and to be mapped separately.

Several pits in this gravel will be found on Clapham Common; but the maximum thickness appears to be less than 10 feet, and no fossils could be discovered in it.

The London Clay occupies two distinct outliers, the one extending westward only as far as Poling, the other commencing a mile to the north-west and stretching continuously in a narrow band nearly to the western edge of our district. Our knowledge of this division has been derived almost entirely from borings and well-sections; for the only exposure of any importance is that seen in the Arundel railway-cutting, which is now much overgrown and obscured by landslips.

At the southern limit of our district almost the whole thickness of the London Clay seems to have been met with in a trial-boring made at Merston for the Bognor Waterworks. The whole of the neighbourhood is obscured by Drift gravel and loam; but the great thickness of the London Clay met with in this boring, and the high dip proved by other wells, suggest that there may be an outlier of Bagshot Sand south of Drayton House. The details of the boring, supplied by Messrs. Docwra & Co., are as follows:—

		Ft.	in.
Made ground and Drift		13	6
London Clay 292½ ft.	Hard blue clay	4	0
	Soft clay with sand	12	6
	Blue clay	16	0
	Sandy clay	2	0
	Blue clay	95	6
	Green sand	1	6
	Hard rock		10
	Blue clay	88	2
	Hard rock	1	0
	Hard blue clay	65	0
	Blue clay	6	0
Reading Beds 99½ ft.	Mottled clay	8	0
	Hard red clay	91	0
	Flints		6
	Chalk and flints	244	6

The two rock-beds may represent the two which form respectively the ledges known as the Barn Rocks and Bognor Rocks on the coast.

No other section in the district equals the one just mentioned in completeness and interest, though a boring at Headhome Farm, in Aldingbourne, proved 235 feet of London Clay, and one at Barnham Junction proved 208 feet. A section and samples of this latter, communicated by the London, Brighton, and South Coast Railway Company, showed:—

		Ft.
Drift		12
London Clay 208½ ft.	London Clay	44
	Sandy loam, with water	thin
	London clay	56
	Rock	1
	Blue clay with septaria	38
	Rock	1
	Blue sandy clay with septaria (stiff at 170 feet)	68½
Reading Beds 109½ ft.	Red and mottled clays	108½
	Bed of flints	1
Chalk		105¾

It will be noticed that in this section again there are two thin beds of rock; but their positions do not correspond with the thin bands found at Merston.

No fossils have yet been recorded from the London Clay of our area, and I have only seen indeterminable fragments in the crushed material brought up by the boring-tools.

CHAPTER VII.

DRIFT.

The drift deposits of this part of Sussex occur in two areas, isolated from one another by the high range of the South Downs; the Downs themselves being free from drift. This isolation, the difference in the character of the deposits, their different mode of origin, and the absence of any clear evidence from fossils, makes any satisfactory correlation between north and south at present impossible. We must, therefore, deal with the two areas separately. Before speaking of the deposits, it will be convenient, however, to sketch in a few words the changes that can be shown to have taken place within the larger district, of which the area now treated is only part.

After the deposition of the Eocene deposits described in the last Chapter, and probably as late as the Miocene period, movements of the earth's crust threw the strata into the folds that have already been alluded to more than once. The principal wave raised the middle part of the Weald high above the area now occupied by the North and South Downs; consequently, the streams received a tendency to flow away from the Wealden axis northward and southward across the Chalk into the London and Hampshire Tertiary basins, each of which basins was drained by a main river, flowing towards the east in the synclinal trough. As time went on, the north and south streams deepened their valleys so greatly that they could not easily be diverted; though tributaries, working east and west along the outcrop of the softer strata, soon lowered their valleys far below the general level of the more slowly denuded chalk downs. Thus there still remain a few large streams, like the Arun, which cut from north to south, straight through the wall-like Chalk-escarpment, whilst many of their newer tributary valleys, which run east and west, would seem to offer a far easier mode of escape to the sea. The main valleys still retain their original course; the smaller valleys must continually shift southward and cut downwards as the Chalk-escarpment recedes.

In addition to the deep trenching of the country by river valleys, the Chichester area shows another feature, which is apt to be overlooked. On reference to the Map, it will be seen that the drift-covered plain around Chichester ceases abruptly at the foot of the Downs, with a nearly straight boundary for over ten miles. This line marks the position, approximately, of an ancient buried and much-destroyed sea-cliff. It will be noticed that the more abrupt rise or slight bluff that marks the cliff does not keep to one geological formation, as does the true sub-aerial escarpment of the Downs. Near Arundel the boundary curves to the east-south-east, so as to cross the Eocene strata and take in part of the Chalk at Highdown Hill, though the exactly similar Chalk and Eocene strata around Angmering and Ford have been planed down to one dead level.

Clay with Flints.

Before dealing with the truly stratified and transported Drift deposits, it will be well to refer to the sheets of stony clay and Tertiary *débris* which cap some of the flatter-topped hills and ridges of the Downs. This Clay with Flints may occur at any height above the sea and cannot be referred to any definite geological period. In this part of the Downs it is confined to areas over which Eocene deposits may have spread within comparatively recent times; it is sometimes very difficult to decide whether a particular patch should be called slightly disturbed Eocene, or mapped as Clay with Flints. It will be understood, from what has just been said, that the material of the Clay with Flints is mainly derived from the destruction of Eocene outliers, the flint pebbles, green-coated angular flints, sarsen stones, quartz-sand, and probably most of the clayey matrix, being of Eocene origin. A considerable number of the angular flints, and part of the fine clayey matrix, have been added, as insoluble residue from the underlying Chalk, which was gradually dissolved away by the percolating rain-water. This solution produces curious vertical hollow cylinders or cones in the Chalk, and these so-called pipes can often be seen in section in quarries. Within the pipe is a column of clay and flints let down from above, the centre of the column often being mainly composed of Eocene material, while the margin and bottom consists of true insoluble residue. It should not be forgotten that only a small part of the Upper Chalk is insoluble, and that this insoluble residue alone would consist mainly of loose flints, and would make a stony desert rather than stiff clayey land.

The distribution of the Clay with Flints will best be understood by reference to the Map. The matrix as a rule is a black or red sandy tough clay, much stained by oxides of iron and manganese, and the nearer the outliers are to Eocene strata the larger the proportion of Eocene pebbles found in them. The Clay with Flints where thick makes a cold wet soil, very different from the ordinary soil of the bare Downs. On it one finds areas of rough coarse grass, brambles, and low bushes. The total thickness seldom reaches 10 feet. A good deal of the weathered flint gravel found in the Valley Drift was probably derived from these sheets of stony clay, and need not represent the contemporaneous destruction of an equivalent amount of flinty chalk.

Southern Area.

We will commence the description of the stratified Drift deposits with the area south of the Downs; for in that area the sheets are nearly continuous, and can be connected with deposits of known date and yielding abundance of fossils not far from Chichester. We must begin with the ancient sea-cliff and the deposits which flank it; for unfortunately we have nothing of earlier Pleistocene date, though an occasional erratic block, washed out of older strata, can be found.

MARINE GRAVELS.

The sea-cliff just mentioned enters the area near Highdown House, where it still makes a bold feature, though no pit shows the actual shore-line, which is hidden by later gravels. South of the stream some of the ancient marine deposits can be traced in the shingly gravel which there appears at the surface. A shallow well at Ferring (just outside the Map) gave still better evidence; for the shingly sand there found was full of periwinkles (*Littorina obtusata*); but the small sample I saw contained nothing else. A new chalk-pit on the south side of Highdown Hill may at any time lay bare the old buried cliff.

Between Highdown and the Arun the old coast-line cuts obliquely across the Eocene strata; and, as we should expect in such soft strata after so long a period, the actual cliff is not easy to trace, and the marine deposits seem to have been swept away by the rush of water from the Downs. The marine deposits found at Ferring have been preserved, it will be noticed by Highdown Hill, which has protected them from the land-water and diverted the floods to the right and to the left.

West of the Arun the marine gravels reappear on Tortington Common as masses of flint shingle at a height of 105 feet. A little nearer the Downs equivalent deposits are seen in two pits in a copse on the north side of the high road one and a half miles west of Arundel. These pits show:—

	Feet.
Angular flint gravel (Coombe Rock) - - - -	2 to 6
Fine buff sand and a few pebbles - - - - -	10 to 15
Chalk (touched)	

The sands reach a height of about 120 feet above Ordnance Datum and correspond closely with the sands at Waterbeach, still to be described. They perhaps represent an ancient sand-dune or sandy beach; but no fossils were observed at this point.

Three-quarters of a mile west of the pits just described, an outcrop of these sands will be found on the edge of the Brinsted valley, immediately east of Slindon Common. Two pits in this outcrop show similar sections, but the Coombe Rock is thicker; the level is about the same. Another smaller outcrop occurs in the little valley which exposes Chalk and Reading Beds south of Slindon Common. A small pit just on the 100 foot contour, and slightly farther from the buried cliff, here shows flint-shingle.

Near Boxgrove this marine sand appears at the surface for nearly three miles; but it only reaches a maximum elevation of 90 feet, and is cut off by the Coombe Rock both on the north and on the south. A pit on the east side of the park belonging to Aldingbourne House showed 20 feet of falsebedded shingle and sand, among the pebbles being found two of quartzite or greywether, one of a coarse purple grit, like that found among the Selsey erratics, and one of basalt. Other pits south of Boxgrove expose from 10 to 15 feet of this shingle and sand, which has all the appearance of a true sea-beach, though here the marine shells have been destroyed by percolating water.

Between this bank of shingle and the old chalk-cliff the fine sands again appear. There is a pit in them close to the road to Eartham, about a quarter of a mile south-west of Park Farm. The cliff must run between the pit and the farm. The top of the sand is here about 130 feet above Ordnance Datum; but of course if this sand, which contains no stones, is merely a sand-dune, it does not prove submergence to quite that extent. Another small patch of this sand will be found at the same level half a mile to the west-north-west, at the south end of Eartham Thicket.

Close to Waterbeach, at the south-east corner of Goodwood Park, will be found a large sand-pit, which is of exceptional interest, for it yields clear evidence of a submergence beneath the sea to the extent of at least 130 feet. This pit seems to lie within a few yards of the old cliff, though the actual cliff-face has not yet been touched. Large blocks of Pholas-bored and worm-eaten chalk are occasionally found in the sand, and part of one of these masses has been placed in the museum at Jermyn Street. The section measured at a time when the pit was exceptionally clear was as follows:—

	Feet.
Coombe Rock—unworn flints in a chalky paste, irregularly decalcified for about a third of its depth. - - - - - - - - -	15
Coombe Rock—stratified and mixed with sand and chalk-pebbles - - - - - - - -	2
Fine buff quartz-sand, with coarser seams full of splinters of flint, and containing occasional small shells. *Balanus* (common), *Mytilus edulis* (fry only), *Tellina balthica* (one valve), *Trophon* (one full-grown) and numerous Foraminifera. Also a boulder of *Pholas*-bored chalk weighing about 2 cwt. - - - - - - - -	15
Tabular concretions of calcareous sandstone - -	¼
Sand as above, a few flint-pebbles near the base -	4
Large flat irregular concretions, in sand - - -	1
Fine sand, becoming loamy, orange, and alternating with thin seams of reddish clay near the base -	2
Waterworn irregular surface of Chalk and flints	

The top of this pit is about 157 feet above Ordnance Datum.

So few species of fossils have yet been found in the Waterbeach pit, that very little can be said as to the climatic conditions which then held. The climate does not seem to have been Arctic, and if, as I think, this beach-deposit is of the same age as the deeper-water clay with southern mollusca found at Selsey, we apparently must be dealing with a true interglacial deposit.*

Immediately south-west of Goodwood House the sands are said again to have been met with, and in Valdoė there is another small pit. At Lavant they seem to have been swept away, but reappear on the west side of the valley in the railway-cutting west of Chichester Barracks. They have not been noticed farther west for some miles, till Portsdown is reached.

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* *See*, Geology of Bognor, *Mem. Geol. Survey* 1897; Reid, Pleistocene Deposits of the Sussex Coast, *Quart. Journ. Geol. Soc.*, vol. xlviii., pp. 344–361 (1892); and Prestwich, *Ibid.*, p. 271.

It is impossible to show on the Map the greater part of the outliers just described, for the sections are nearly all pits dug through newer deposits, or are else in outcrops too narrow to be engraved.

COOMBE ROCK, VALLEY GRAVEL, AND BRICKEARTH.

The term "Coombe Rock" is applied in Sussex to a faintly-stratified deposit of unworn or shattered flints mixed with chalk, which occupies the lower part of the valleys in the Downs, and spreads out in a wide sheet over the maritime plain. This deposit is very peculiar, and though it tends to merge into ordinary terrace-gravel when traced up valleys which still contain living streams, it is neither forming now nor is a quite similar deposit of common occurrence out of Sussex. Its probable mode of origin has been described elsewhere.* It seems to point to Arctic conditions affecting a region not actually smothered under ice, as so much of Britain was during the Glacial Epoch. It suggests violent spring floods, which rushed down the valleys, thawing, tearing up, and carrying away the chalk and spreading sheets of chalk and flint rubble over the plain in wide confluent deltas. At the present day most of the valleys are dead, never contain running water, and remain unchanged from year to year, except for the gradual accumulation in their bottoms of a layer of loose flints dislodged from the steep sides. This talus and rainwash, however, is unlike Coombe Rock, which is full of unweathered flints and of lumps of chalk, even at a distance of several miles from the Downs.

The Coombe Rock yields occasional teeth of horse and mammoth, usually much weathered, as though they had long lain on the surface before being swept down by the floods. In this region no other fossils have been noticed, except one or two worked flint-flakes. At Salisbury, however, a large Arctic fauna has been found. The stony brickearth, which so often replaces part of the Coombe Rock over certain areas, might yield fossils, were it not usually decalcified by the action of percolating water.

Coombe Rock is extensively dug for road-metal, part of the chalky matrix being screened away, the remainder helping to make the material bind. Or else the upper decalcified and the lower chalky material are mixed, so as to give the right proportion of chalk. The distinction between red and white gravel, which are often supposed to be different deposits,† is due merely to the subsequent dissolving away of the chalky matrix, leaving a mass of rusty flints and clay. The Coombe Rock has been dug to a depth of 15 feet in a large pit at Portfield, near Chichester, for ballast on the railway. Though this pit is constantly being worked, contemporaneous fossils do not seem often to be found. None could be procured from the men, who brought me only some echinoderms in flint, and a handful of coins, mostly Roman. Various other pits, always changing, will be found; the one at Waterbeach, already described, being of particular interest as showing the relation of the Coombe Rock to the underlying stratified sands. An excellent section must once have been visible in the long cutting occupied by the branch canal near Chichester.

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* *Quart. Journ. Geol. Soc.*, vol. xliii., p. 364 (1887).

† *See* Godwin-Austen, *Quart. Journ. Geol. Soc.*, vol. xiii., p. 47

The Brickearth, which has been mapped as a separate division, is really a modified Coombe Rock; and passes both horizontally and vertically by imperceptible gradations into that deposit. In fact the transition is so gradual that great doubt was felt as to which areas should be included in each, much of the material being "shrave," a local name for such loamy gravels or gravelly loams as are too stony for brickearth and too earthy for use as gravel. Shrave was formerly of more importance as being a convenient material for building mud walls, an art now seldom practised.

The Coombe Rock, as already mentioned, when traced into the Arun Valley, tends to pass into material more like ordinary valley deposits; as though that valley was then occupied by a perennial stream, which however flowed at a somewhat higher level than the present channel. In the Arundel railway-cutting the gravel runs up 50 feet above Ordnance Datum. At Warningcamp its upper edge is slightly higher; but its lower edge seems to pass under the marsh. A pit in Warningcamp, about 30 feet above the marsh, shows a curious transition from Coombe Rock to ordinary washed river-gravel. The section is: —

	Feet
Coombe Rock — angular flints in a matrix of fine rolled chalk-gravel and a little marl, slightly bedded. This weathers irregularly and in pipes into angular unstratified flint-gravel in a blackish clayey matrix. No fossils yet found - - -	12
Finer, more worn, and distinctly falsebedded gravel, with nests of sand. In the lower half are numerous fragments of Greensand-chert and of Wealden ironstone, often large - - - -	4

Teeth of elephant are said to have been found at Warningcamp, but it is not clear from which bed they were obtained. In the small coombe north of Warningcamp there is a narrow terrace, apparently of Valley Gravel or Coombe Rock, about 15 feet above the bottom of the coombe and stretching for a quarter of a mile along the north side. The road-cutting north of this coombe passes through similar gravel to that seen in the pit; but only about 8 feet is seen. It contains Wealden stones, and rests on at least 10 feet of chalk-rubble in a marly paste, also containing occasional fragments of Greensand-chert. In this neighbourhood, therefore, clean river gravel would seem to alternate with Coombe Rock.

Wepham, Burpham, and Peppering are built on a terrace cut into the Chalk, and sloping upwards to about the 100 foot contour; but no gravel was observed on this terrace except at one point. In the steep river-bluff north of Peppering, close to the path, chalk has been dug, and in it is seen a pipe full of ferruginous sand with pieces of Lower Greensand ironstone. Another pipe in the Burpham cliff contains very fine white or buff sand. Elephant-teeth have been found at Burpham

Offham and South Stoke show gravelly terraces; North Stoke and Houghton are built on similar platforms, with merely a trace of gravel. The most northerly of these terraces rises about 45 feet above the marsh.

The reason for tracing thus minutely the terrace-features through the valley of the Arun, is that these terraces seem at present to offer the only means of connecting the drift-deposits south of the Downs with those on the north. The continuity, however, is not unbroken, and it is still doubtful whether the terrace just described is represented by the higher or by the lower series of gravels in the northern area, or by both. I suspect that none of the gravels coloured pink on the Map in the northern area are so old as the raised beach-deposits of Goodwood; and that the two series around Midhurst and Pulborough may be equivalent to the two Coombe Rock terraces at different levels seen at Lavant. The evidence thus far obtained in Sussex, suggests a considerable lowering by denudation of the floor of the Wealden area in late-Pleistocene times. Nowhere can the Pleistocene marine deposits be traced through the gorges of the South Downs or into the Weald, though much of the Weald lies below the level of the raised beach. Perhaps some of the higher plateau-gravels may be fluviatile deposits belonging to that period of depression.

The next section will describe the Pleistocene deposits and features of the northern area; it is mainly by Mr. Lamplugh.

NORTHERN AREA.

Within the part of our area which lies north of the Downs, Mr. Lamplugh finds that the oldest superficial deposit is a coarse flinty rubble, which forms an irregular capping on plateaux of limited extent on the Folkestone, and occasionally on the Sandgate Beds south of the Rother valley. These little plateaux, much dissected by erosion, slope gently northward (*i.e.*, away from the South Downs), but end off boldly above the depression occupied by the Gault in steep bluffs simulating an escarpment, sometimes 50 to 80 feet high. The rubble on these plateaux has an extreme depth of 9 or 10 feet in "piped" hollows, but is oftener a mere ragged film through which the underlying formation continually breaks. It is best developed on the commons of Heyshott, Ambersham, Graffham, and Coates and is much dug for road mending. It is again found, though in less quantity, on the higher ground occupied by the Folkestone Beds to the east of the Arun, at Rackham, Parham Park, Kithurst, Sullington Warren, and Longbury Hill, forming little plateaux at varying elevations, apparently the remnants of an old surface which sloped westward towards the Arun and also northward from the Downs. The remarkable persistence of this drift on the Folkestone Beds, while it is scarce or absent on the neighbouring formations, seems to be due to the greater height of the outcrop of that group, which, perhaps, thus alone preserves portions of the ancient surface on which the rubble was deposited. This material was a subject of discussion nearly fifty years ago by Sir R. I. Murchison,* and more recently by Mr. J. Vincent Elsden.† Its accumulation probably dates back to the glacial period, and must have taken place under peculiar physical conditions. That the plateaux have suffered very little surface-erosion since prehistoric times, is shown by the position of the tumuli on some of the spurs overlooking the Gault depression. There is great difficulty in distinguishing between the lower patches of this high-level drift and the higher of the true river gravels, though frequently the presence of fragments of chert, sandstone, etc., in the latter, is sufficient to identify them.

Where the escarpment of the Hythe Beds is high, as between Petworth and the Arun, patches of angular cherty rubble, derived from that source, occur as a thin capping on hills of Weald Clay below the escarpment, and sometimes half a mile or more distant from it. These usually lie opposite coombe-like indentations in the escarpment, and are probably equivalent to the flinty rubble which occupies a similar though more distant position in regard to the South Downs. Both would require peculiar physical conditions for their production, and are probably the relics of some stage of the glacial period.

Gravelly deposits, undoubtedly connected with the erosion of the present valleys, are found chiefly in the form of deltas around the junction of tributary streams with the main valleys, their materials being mainly derived from the high-level drifts. These gravels, in the absence of sections, are sometimes difficult to detect, owing to the deep covering of stoneless sandy wash in the Lower Greensand tract, and of clayey wash in the Wealden area, which form soils indistinguishable from those of the rocks below.

In the vicinity of the Arun, gravels of this class occur at varying elevations, even capping high ground adjacent to the river, as at Lee Farm in the Weald, and at Greatham on the Lower Greensand. They are then, as above stated, scarcely separable from the high-level drift. It is indeed evident that the subaerial erosion of the land has gone on without interruption since the period of the high-level drift; there is no trace here, as already remarked, of the marine stage recognised at corresponding elevations on the southern side of the South Downs, which therefore probably preceded the earliest drift now existing in the interior.

ALLUVIUM.

The Alluvium of the Arun forms a wide and perfectly level plain, the marshes ending abruptly against rising ground on either side. It will be noticed that this flat does not change slowly into dry land and sloping bank, or form a curved valley-bottom like that of the Lavant. On drawing a transverse section across the Lavant valley the outline will be found to follow an unbroken sweeping curve. But a section across the Arun valley is different; the flowing curve of the hills on either side is not continued by the present valley-bottom; but if the curves are continued they will be found to plunge beneath the Alluvium, to meet 100 feet or so beneath the present marsh-level. On examining the records of borings in the Alluvial flat of the Arun, it will be found that the curve of the rocky floor does follow the same law as in other valleys; but that the true bottom of this valley is now much below the level of the sea. The land at one time stood higher, so that the valley could be cut below the present sea-level; but since that time subsidence has turned this valley into a long harbour or fiord, which has gradually become silted up till at last the harbour has changed to a marshy flat raised nearly to the level of the highest tides. This deep trenching, subsequent depression, and ultimate silting up of the valleys is not confined to the Arun; it affects the whole of the estuaries and harbours round our coasts. The depression seems to have taken place at so recent a date that great part of the harbours are still only partly silted up, though many are rapidly becoming obliterated. The ancient fiord of the Arun is silted up; but Chichester harbour, which happens to receive no stream of importance, and therefore little mud, remains only partly filled.

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* *Quart. Journ. Geol. Soc.*, vol. vii., pp. 351-361.

† *Ibid.*, vol. xliii., pp. 637-656.

Some borings for wells between Arundel Station and Arundel throw a great deal of light on the contour of the submerged valley-bottom. A boring at Arundel Station is said to have reached the chalk floor beneath 100 feet of marsh clay, and another boring at the Station Inn was 150 feet deep in marsh clay. The strike, however, suggests that possibly in each of these wells there may have been some Reading Beds included in the "marsh clay." Another well, at a new house on Arundel Causeway, about midway between the two bluffs, is open to no such question, and it shows 84 feet of marsh clay above the chalk. Another boring, at Warningcamp crossing, shows still deeper Alluvium, Chalk being reached at 117 feet below the marsh. On the Arundel side of the marsh a boring at the coal yard penetrated 38 feet of marsh deposits before reaching Chalk—showing that the steep bank must be continued downwards to below the level of low water. The superficial layers of the Alluvium, thrown up in digging the foundations of a new house on Arundel Causeway, were composed of estuarine warp full of *Scrobicularia* in the position of life.

CHAPTER VIII.

ECONOMIC GEOLOGY.

Within the area with which we are now dealing there are no mines, and no quarries of much importance, the economic applications of geology being almost confined to the supply of building materials for local use, of stone for road-making, to water supply, and to agriculture.

BUILDING MATERIALS.

Over most of the district brick is now the building material, though other materials, such as rough flint, sandstone, and dob, or mud mixed with stones, were freely used in the older buildings. The various building stones will be taken in order.

Hythe Beds.—These yield irregular bands of calcareous sandstone, which is much used for building around Pulborough. The stone is often hard and cherty, or passes into chert, which is dug for road-metal.

Folkestone Beds.—A little ferruginous sandstone is occasionally found, and has been used for walls, but it is of no economic importance.

Upper Greensand.—Neither the malm-rock nor the green sandstones are now quarried, both seeming to be too soft to be of any value in this area.

Grey Chalk.—A little of this rock has been used for interior work, as it is very easy to work. It will not stand the weather.

White Chalk.—The harder Middle Chalk has also been used for interior work, but it has an irregular curved jointing, and usually comes out in small pieces. The flints of the Upper Chalk, more or less trimmed, have been used extensively in the old buildings, especially in the churches. They are almost indestructible, and when carefully squared and built with close joints, they make a wall which is probably less affected by the weather than any other in Britain. Except occasionally in the churches, this fine squared-flint building is seldom used, the art of squaring flints needing special skill, and being quite unlike ordinary mason's or bricklayer's work.

Coombe Rock.—This deposit also yields abundance of large flints for building; but they are commonly more stained than those obtained direct from the Chalk. Flints from drift-deposits, or those that have long been exposed to the weather, are also more difficult to face or square.

LIME.

The Middle and Upper Chalk everywhere yield ordinary lime of very similar character. The Lower Chalk is more marly, and yields hydraulic lime. The custom of chalking the land has now almost been given up in this district, though lime is often used.

SAND.

Some of the best sand in the district is that obtained from the whiter parts of the Folkestone and Sandgate Beds; though there are sand-pits in various parts of the Lower Greensand. Sand from the Upper Greensand is usually full of green or rusty specks, and is not so clean. The southern part of the area is badly supplied, the only clean sands there found being the fine dust-like sands of Waterbeach and other localities near the old raised-beach.

ROAD-METAL.

For road metal the chalk-flints are the great source of supply, those collected from the fields being tougher and better than those obtained direct from the chalk-pits or from the gravel. In the area too far from the flints, the chert found in the Hythe Beds and the concretionary ironstone from the Folkestone Beds are used.

WATER SUPPLY.

Over the greater part of the area there is little difficulty in obtaining good water; for plenty is usually to be found in the Chalk, and the Upper Greensand may yield supplies of good quality. As this subject has been dealt with in a recent Memoir,* there is no need to go over the ground in detail; the areas where difficulty is felt should, however, be mentioned. On the Weald Clay the supply is often very uncertain, and the water not palatable; the only source (beyond the very unsafe surface wells) is the thin sand beds which occur irregularly in the clay. It is almost useless to make deep borings; though occasionally one may yield a moderate supply of water. The Gault yields no water; but a good supply can be obtained by boring to the Folkestone Beds; any small quantity found in the Gault should be carefully stopped out, and not allowed to mix with that from below—its flavour is very disagreeable.

Over the exposed Eocene clays, water is readily obtained by boring to the Chalk; the Eocene itself here yielding no water. Where the Chalk and Eocene are overlaid by Coombe Rock there is commonly plenty of water in the superficial deposits; but this source is very liable to surface contamination, and should not be used if it can be avoided. The water from the gravel is harder than that from the Chalk.

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* The Water Supply of Sussex from underground sources, *Mem. Geol. Survey*, 1899.

APPENDIX.

List of Principal Works on the Geology of the District.

1822. Mantell [Dr.] G. A. The Fossils of the South Downs, or Illustrations of the Geology of Sussex. 4to. London.

1826. Mantell [Dr.] G. A. On the Iron Sand Formation of Sussex. *Trans. Geol. Soc.*, Ser. 2, vol. ii., p. 131.

Murchison [Sir] R. I. Geological Sketch of the north-western Extremity of Sussex. *Ibid.*, p. 97.

1827. Mantell [Dr.] G. A. Illustrations of the Geology of Sussex. 4to. London.

Martin, P. J. On the Geology of the Vicinity of Pulborough, Sussex. *Proc. Geol. Soc.*, vol. i., p. 19.

1828. Martin, P. J. A Geological Memoir on a part of Western Sussex. 4to. London.

1833. Mantell [Dr.] G. The Geology of the South-east of England. 8vo. London.

1836. Fitton, Dr. W. H. Observations on some of the Strata between the Chalk and the Oxford Oolite in the south-east of England. *Trans. Geol. Soc.*, Ser. 2, vol. iv., p. 103.

1841. Martin, P. J. On the Relative Connection of the Eastern and Western Chalk Denudations. *Proc. Geol. Soc.*, vol. iii., p. 349.

1850. Dixon, F. The Geology and Fossils of the Tertiary and Cretaceous formations of Sussex. 4to. London. Ed. 2 in 1878.

1851. Martin, P. J. On the Anticlinal Line of the London and Hampshire Basins. *Phil. Mag.*, ser. 4, vol. ii., pp. 126, 189, 278, 366, 471. See also vol. xii (1856), p. 447 and vol. xii. (1857), pp. 33, 109.

Murchison [Sir] R. I. On the distribution of the Flint Drift of the south-east of England, on the Flanks of the Weald, and over the surface of the South and North Downs. *Quart. Journ. Geol. Soc.*, vol. vii., p. 349.

1855. Godwin-Austen, R. A. C. On Land Surfaces beneath the Drift Gravel. *Quart. Journ. Geol. Soc.*, vol. xi., p. 112.

1856. Martin, P. J. On some Geological Features of the Country between the South Downs and the Sussex Coast. *Quart. Journ. Geol. Soc.*, vol. xii., p. 134.

1857. Godwin-Austen, R. A. C. On the Newer Tertiary Deposits of the Sussex Coast. *Quart. Journ. Geol. Soc.*, vol. xiii., pp. 40-72.

1859. Prestwich [Sir] J. On the Westward Extension of the old Raised Beach of Brighton; and on the extent of the Sea-Bed of the same Period. *Quart. Journ. Geol. Soc.*, vol. xv., p. 215.

1869. Maw, G. [Letter] On a section of the Gault and Lower Greensand, at Lower Fittleworth, Sussex. *Geol. Mag.*, vol. vi., p. 335.

1875. Topley, W. The Geology of the Weald. (*Mem. Geol. Survey*). 8vo. London.

1886. Elsden, J. V. Superficial Geology of South Portion of Wealden Area. *Quart. Journ. Geol. Soc.*, vol. xlii., p. 637.

1887. Reid, C. On the Origin of Dry Chalk Valleys and of Coombe Rock. *Quart. Journ. Geol. Soc.*, vol. xliii., p. 364.

1892. Prestwich [Sir] J. The Raised Beaches, and "Head" or Rubble-drift, of the South of England. *Quart. Journ. Geol. Soc.*, vol. xlviii. The Sussex Coast Plain, pp. 271-273.

Reid, C. The Pleistocene Deposits of the Sussex Coast, and their Equivalents in other Districts. *Ibid.*, pp. 344-361.

1899. Whitaker, W., and C. Reid. The Water Supply of Sussex from underground sources. (*Mem. Geol. Survey*). 8vo. London.

1900. Jukes-Browne, A. J. The Cretaceous Rocks of Britain. Vol. I.—The Gault and Upper Greensand of England. With contributions by W. Hill. (*Mem. Geol. Survey*). 8vo. London.

[Vols. II. and III. dealing with the Chalk are in the Press.]

INDEX.

Actinocamax quadratus, zone of, 18, 19, 27, 30.
Adur Valley, 14, 15.
Adversane, 6.
Agriculture, 1, 4, 19.
Aldingbourne, 35.
—— House, 39,
Alluvium, 44, 45.
Amberley, 16 17, 22, 23, 25, 26.
Ambersham, 43.
—— Common, 7, 11.
Ammonites (*Acanthoceras*) *rotomogensis*, 20.
—— (*Hoplites*) *interruptus*, 14, 15
—— —— —— zone of, 13.
—— *lautus*, zone of 13.
—— *mammillatus*, zone of, 13, 15.
—— *Mantelli*, 22.
—— *rostratus*, zone of, 13, 16.
—— (*Schloenbachia*) *rostratus*, 14, 16.
—— —— *varians*, 20-22.
—— —— —— zone of, 18.
Ananchytes, 28.
Angmering, 33, 37.
Anticlinal axes, 2.
Arctic conditions, 41.
Area of the district, 1
Arun River, 1, 6, 8, 9, 17, 22, 25, 34, 37, 39, 43, 44, 45.
—— Valley, 5, 14, 18, 27, 28, 42–44.
Arundel, 1, 25, 30, 32, 34, 35, 37, 39, 42, 45.
—— Causeway, 45.
—— Gas Works, 34.
—— Station, 33, 45.
Atherfield Clay, 7, 8.
Avicula, 9.

Bagshot Sand, 35.
Balcombe Pit, 25.
Barlavington, 16, 17, 24, 26.
Barnetts Mill, 11.
Barnham, 2.
—— Junction, 34, 35.
Barn Rocks, 35.
Barrois, Prof. C., 25.
Bedham, 8.
Beachy Head, 17.
Belemnite Marls, 22–24.
Belemnitella mucronata, zone of, 18, 27.
Belemnites minimus, 16.
Bepton Down, 24.
Beryx ornatus, 25, 26.
Bignor, 17, 26.
Bignor Park, 15.
Billingshurst Station, 6.
Binderton, 23.
Black Rabbit Inn, 30.
Blackdown Sands, 13.
Bognor, 1, 9.
—— Rocks, 34, 35.
—— Waterworks, 35.
Bound House, 15.
Bow Hill, 27.
Boxgrove, 39.
Brachyphyllum, 6.
Brickearth, 41, 42.
Brinksole, 9.
Brinsted, 34.
—— Valley, 39.
Bristow, H. W., iii.
Broadfordbridge, 6.
Brydone, R. M., 15, 16, 20, 21, 28, 29.
Building Materials, 46.
Buriton Farm, 24.
Burpham, 30, 32, 42,
Burton, 15.
—— Church, 13.
Burwells Farm, 30
Bury, 2, 16, 22, 25.
—— Hill, 22.

Calcareous flagstone in the Weald, 6.
—— sandstone in the Chalk, 23
Carstone, 12.
Chalk, 2, 16–42, 45–47.
—— Marl, 17–23.
—— Rock, 23–27.
Chantry Hill, 23.
Chichester, 1 2, 17, 24, 27, 31, 33, 34, 37, 38, 41, 42.
——Harbour, 45.
Chilgrove, 27.
Chloritic Marl, 16.
Clapham, 34, 35.
Clausilia Rolphii, 22.
Clay with Flints, 38.
Climate, 18, 41.
Coates, 43.
Cocking, 17, 19, 24.
Codmore Hill, 12.
Coombe Rock, 39–43, 46, 47.
Cowdray Ruins, 7, 11.
"Creep," 5.
Crypt Farm, 19.

Decoy Cottage, 33.
Denudation, 1, 18, 33, 37–45.
Devon, Blackdown Sands of, 13.
Didling, 16.
Dip exaggerated by weight of hill, 19.
Disturbances 2, 3, 26, 33, 35.
Dixon, F., 25.
Docwra & Co., 35.

Dorset, Gault of, 13.
Dover, 8.
Downs, 1, 18–33, 37–39, 43, 44.
Drainage of the area, 1, 37.
Drayton House, 35.
Drew, F., iii.
Drift, 2, 3, 34, 35, 37–45.
Duke & Ockenden, 10, 33.
Duncton, 15, 16, 20, 25, 29.
—— Down, 18.
—— Hanger, 24.
—— Hill, 29.
Dundas, Hon. W. F., 30.

Eartham, 40.
East Dean, 26.
Echinocorys scutatus, 28.
Elephants' teeth, 41, 42.
Elevation of land, 37.
Ellis and Sons, 34.
Elsden, J. Vincent, 44.
Elstead Station, 15.
Elsted, 16.
—— Green, 16.
Enoploclytia Leachi, 25.
Eocene, 2, 17, 18, 31, 33–39, 47
Erosion, 1, 18, 33, 37–45.
Estuarine mud, 45.

Ferring, 39.
Fishbourne, 34.
Fittleworth, 9–12.
—— Station, 13.
Folkestone, 13,
—— Beds, 7, 10, 12, 13, 43, 46, 47.
Ford, 37.
Formations, List of, 1.
Fuller's Earth, 24.

Galt, *see* Gault.
Gatehouse's Brewery, 17, 27.
Gault, 12–17, 43, 44.
Glacial Epoch, 41.
Goodwood, 17, 27, 30, 43.
—— House, 32, 40.
—— Park, 18, 40.
Gould, C., 17.
Graffham, 17, 24, 43.
Gravel-pit Plantation, 12.
Grayets, 16.
Greatham, 44.
Greenhurst, 8.
Greensand-chert, 7, 42.
Grey Chalk, 18, 46.
Gunter's Bridge, 5.

Hampshire Basin, 2, 33, 37.
Hangers, 22.
Hardham, 15,
Harwood's Green, 7.
Hassock, 8–10.
Hastings Sands, 6.
Hawkhurst Lodge, 5.
Hawkins, C. E., 16.
Headhome Farm, 35.
Helix obvoluta, 22.
Hesworth Common, 12.
Heyshott, 19, 43.
Highdown Hill, 2, 27, 33, 37, 39.
Hill, W., 22, 25, 28–30
Hills & Hamper's Farm, 9.
Holaster planus, 26, 28, 29.
—— —— zone of, 18, 28.
—— *subglobosus*, zone of, 18, 21.
Hollow-ways, 17.
Houghton, 22, 23, 25, 26, 29, 43.
Hurston Place, 12.
Hythe Beds, 4, 7–12, 44, 46.

Inoceramus concentricus, 14, 15.
—— *mytiloides*, 24, 25.
Interglacial deposit, 40.
Iron-sand, 7, 11.
Ironstone nodules, 11, 12, 15, 42.
Isle of Wight, 8.

Jackets Hill, 9, 10.
Jermyn St. Museum, 40.
Jukes-Browne, A. J., 13–16, 19–30, 32
June Lane, 7, 11.
Jurassic, 2.

Kennels, Goodwood, 30.
King John's Walk, 11.
Kitchin, Dr. F. L., 11, 23.
Kithurst, 43.

Lambdown Hill, 27.
Lamplugh, G. W., 4–13, 15, 16, 43, 44.
Lancing, 30, 33.
Landslips, 33.
Lavant, 40, 43, 44.
—— River, 1.
—— Valley 26.
Lee Farm, 6, 44.
Le Grand & Sutcliffe, 30, 31.
Lima Hoperi, 29.
Lime, 46.
Linch Down, 1, 18, 24.
List of Formations, 1.
Little Bognor, 9.
—— Common, 9.
Littorina obtusata, 39.
London Basin, 37.
London, Brighton and South Coast Railway, 6, 35.
London Clay, 33–36.
Longbury Hill, 43.
Lording's Farm, 6.
Lower Chalk, 2, 17–23, 25, 31.
—— Cretaceous, 2, 4–12.
—— Fittleworth, 14.
—— Greensand, 4, 7–12, 15, 43, 44, 47.
—— —— ironstone, 42.

Macropoma Mantelli, 25.
Malm, 16, 17.
Mammoth, 41, 42.

Manor Farm, 26.
Marehill, 12.
Marine Gravels, 39–41.
Marringdean Farm, 6.
Marsh clay, 45.
Marsupites testudinarius, 28.
—— zone of, 18, 30.
Martin, P. J., 4–6, 15, 16.
Maw, G., 14.
Melbourn Rock, 22–25.
Merston, 35, 36.
Micraster coranguinum, 28-30.
—— ——, zone of, 18, 30.
—— *cortestudinarium*, 28, 29.
—— ——, zone of, 18, 29.
—— *praecursor*, 29.
Middle Chalk, 2, 18–20, 23–27, 31, 46.
Midhurst, 1, 7, 10, 12, 13, 15, 43.
—— Waterworks, 9.
Murchison, Sir, R. J., 44.
Museum of Practical Geology, 40.

Newton, E. T., 11.
Nodular Chalk, 24, 25.
North Stoke, 43.

Offaster pillula, 30.
Offham, 43
Oldhouse Farm, 6.
Onchotrochus, 20.
Onychiopsis Mantelli, 6.
Ostrea lunata, zone of, 18.

Pagham, 1.
Palæontological zones, 13, 18.
Paludina-limestone, 4–6.
Parham Park, 43.
Park Farm, Aldingbourne, 40.
—— ——-Arundel, 34.
—— ——Pulborough, 12.
—— Mound, 12.
Patching, 33.
Pecten asper, zone of, 13.
Peppering, 42.
Pepper's quarry, 22.
Petersfield, 13.
Petworth, 1, 4, 5, 8, 44.
—— Station, 13.
Pholas-bored Chalk, 40.
Phosphatic concretions, 8, 15.
Pipes, 38, 43.
Pitsham, 15.
Plants from the Wealden, 6
Plateau deposits, 38, 43, 44.
Pleistocene, 37–45.
Plicatula pectinoides, 16.
Poling, 35.
Pollicipes glaber, 16.
Portfield, 41.
Portsdown, 40.
Pulborough, 1, 4, 7, 9, 10, 12, 15, 43.

Rackham, 43.
Radiolites 25.
Raised beach, 37, 39, 40.
Reading Beds, 33, 34, 45.
Redhill, 8.
Rhodes, J., 29, 30.
Rhynchonella Cuvieri, 18, 24, 25.
——*plicatilis*, 28, 29.
——*reedensis*, 28.
Road metal, 41, 47.
Roman coins, 41.
——Road, 22.
Rother River, 11.
——Valley, 43.
Rowe, Dr. A. W., 28.

Salisbury, 41.
Sand, 47.
Sandgate, Beds, 7, 10–12, 43 47.
Sargent, F. 24.
Scaphites œqualis, 20.
Scrobicularia, 45.
Sea-cliff, buried, 37, 39, 40.
Selbornian, 13–17.
Selham, 7, 11.
Selsey, 39, 40.
Septaria, 34.
Septifer (*Modiola*) *lineatus* 30.
Seward, A. C., 6.
Shrave, 42.
Singleton, 27.
Sinking of land, 45.
Slindon Common, 39
Soils, 1, 4, 19.
South Downs, 1, 17, 18–33, 37, 39, 43, 44.
——Stoke, 33, 43.
Spondylus latus, 26.
——*spinosus* 26.
Stane Street, 22.
Steyning, 16
Storrington, 2, 4, 8, 10, 17.
Stoughton, 23.
Sullington 14.
——Hill, 23.
——Warren, 43.
Sunwood, Farm, 17, 19.
Sussex Marble, 4–6.
Sutton, 16, 17.

Terebratula in pyrites nodules, 25.
——*carnea*, 28.
Terebratulina gracilis, 26.
——zone of, 18–25.
Thakeham Church, 8.
Threal's Farm, 12.
Tillington, 9.
Toat Farm, 5.
——Wood, 5.
Topley, W., 13–15.
Tortington, Common, 34, 39.
Trees of the district, 1, 18.

Treyford 23.
Trotton, 10.
Turonian, 25.

Upper Chalk, 18, 23, 25–28, 32, 38, 46.
—— Greensand, 13, 16, 17, 46, 47.
—— Mill, 9.
—— Waltham, 2, 23, 26.

Valdoe, 40.
Valley Gravel, 41–43.
Variegated Series of Wealden, Isle of Wight, 5.
Ventriculites cribrosus, 30.

Walberton Brewery, 34.
Warminghurst, 8.
Warningcamp, 30, 42, 45.
Washington, 12.
Water Supply, 4, 30, 31, 34, 35, 47.
Waterbeach, 39–41.
Watersfield, 2.
Weald, 1–4, 18, 43.
—— Clay, 2–8, 47.
Wealden axis, 37.
—— ironstone in Drift, 42.
—— Shales, Isle of Wight, 5.
Weichselia Mantelli, 6, 7, 11.
Wepham, 42.
West Burton Hill, 22.
—— Chiltington, 4, 12.
—— Dean, 2, 23, 26, 27.
Westerfield, 2.
Westhampnett, 34.
White Chalk, 46.
Woodcot Farm, 17.
Woodlands, 1, 18.

Zone of *Actinocamax quadratus*, 18, 19, 27, 30.
—— *Ammonites interruptus*, 13.
—— —— *lautus*, 13.
—— —— *mammillatus*, 13, 15.
—— —— *rostratus*, 13.
—— —— *varians*, 18.
—— *Belemnitella mucronata*, 18, 27.
—— *Holaster planus*, 18, 28.
—— —— *subglobosus*, 18, 21.
—— *Marsupites testudinarius*, 18, 30.
——*Micraster coranguinum*, 18, 30
————*cortestudinarium*, 18, 29.
——*Ostrea lunata*, 18.
——*Pecten asper*, 13.
——*Rhynchonella Cuvieri*, 18, 24.
——*Tersbratulina*, 18, 25.

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